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The role of energy diversification policy in enhancing the sustainability of Omani energy sector
Middle East & Mediterranean studies

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THE ROLE OF ENERGY DIVERSIFICATION POLICY IN ENHANCING THE SUSTAINABILITY OF OMANI ENERGY SECTOR

Middle East & Mediterranean Studies

Badar Ali Zahir Al Hinai

This Thesis is submitted for the degree of Doctor of Philosophy of King's College London
King's College London

2018

Abstract

Much research has previously been done into the benefits of energy diversification for national economies; however, these studies have focused on oil-importing countries. This study examines how diversification of the energy sectors in oil-exporting countries could shift the reliance on depletable energy resources to a more sustainable model of renewable energy resources. This study extends the existing literature on energy diversification from oil-importing countries to the previously unstudied region of oil-exporting countries (GCC countries), with a focus on Oman. It fills a gap in worldwide knowledge about energy sustainability in countries which have a unique economic structure where the economy depends majorly on oil and gas revenues. By distinguishing rules and regulations, technology choices, and policies and strategies according to current energy usage, the thesis explains why oil-exporting countries such as Oman have been slower than other parts of the world in implementing energy diversification policy to enhance their energy sustainability, despite having made efforts to substantially improve their oil extraction techniques. This failure to diversify to renewable resources is largely because of the absence of suitable energy policy, as well as oil and gas abundance and large government subsidies that reduce costs of energy use for residents, both of which encourage inefficient energy use and increasing demand. By using a primary mixed methods approach of semi-structured interviews (25 interviews with government officials, academics, and private sector employees) and a case study research design, the study shows that the impact of energy diversification policy in the energy sector of Oman is poor, mainly because of inadequate political will and the heavily fossil fuel-dependent energy structure of Oman. Based on these findings, the study proposes ways in which oil-exporting countries can reduce their local dependence on oil and gas resources and increase their energy efficiency and conservation measures. Policy makers should use the findings of this study to create strong renewable energy policies, academics should use them to further focus on this important subject and private sector companies in the energy field can also benefit by implementing some of the energy-saving measures described.

Acknowledgements

I would like to take this opportunity to express my feelings and happiness of having studied at King's College London. The study would not have been possible without the encouragement and support of the university and the department of Middle Eastern Studies. I would like also to express my high appreciation to the Omani government for providing me the financial support to pursue this PhD research work, especially the Research Council of Oman. I am indebted to my supervisors, Dr. Mayssoun Sukarieh, Professor Rory Miller, and Dr. Ashraf Mishrif, my three supervisors, for their guidance with wisdom and unlimited support throughout this research work. Also, I'd like to thank Professor Michael Kerr and Dr. Stacey Gutkowski for their vital help, support and encouragements. Especial thanks are due to individuals who facilitated and took part in the semi-structure interviews. My deepest appreciation and most heartfelt thanks go to my mother and my brothers and sisters for their encouragement and their prayers for me to achieve success in this research work. Finally, very special thanks to my wife Um Hilal and my children for their sacrifices, support and encouragement throughout the entire journey. I dedicate this work to my beloved country, the Sultanate of Oman.

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Abbreviations

AAEA:	Arab Atomic Energy Agency
AER:	The Authority for Electricity Regulation of Oman
AIP:	Australian Institute of Petroleum
BP:	British Petroleum
BPD:	Barrels Per Day
Btu:	British thermal units
CBO:	Central Bank of Oman
CSP:	Concentrated solar power
DPS:	The Dhofar Power System
DSM:	Demand Side Management
EIA:	U.S Energy Information Administration
EOR:	Enhanced Oil Recovery
ESCWA:	Economic and Social Commission for Western Asia
GCC:	Gulf Cooperation Council
GDP:	Gross Domestic Product
GHG:	Greenhouse Gases Emissions
GW:	Gigawatt
IAEA:	International Atomic Energy Agency
ICT:	Information and Communication Technology of Oman
IEA:	International Energy Agency
IMF:	International Monetary Fund
IRENA:	International Renewable Energy Agency
JICA:	Japan International Cooperation Agency
km:	Kilometre
Ktoe:	One Thousand Tons of Oil Equivalent
kW:	Kilowatt
MECA:	Ministry of Environment and Climate Affairs of Oman
MENA:	Middle East and North Africa
MIS:	Main Interconnected System
MNE:	Ministry of National Economy of Oman
MNSCF:	Million Standard Cubic Feet
MOG:	Ministry of Oil and Gas

MW:	Megawatt
NCSI:	National Centre for Statistics and Information
OECD:	Organisation for Economic Co-operation and Development
OPEC:	Organization Petroleum Exporting Countries
OPWPC:	Oman Power and Water Procurement Company
PAEW:	Public Authority for Electricity and Water
PDO:	Petroleum Development Oman
PV:	Photovoltaics
RAEC:	The Rural Area Electricity Company
RASERG:	Renewable & Sustainable Energies Research Group
RO:	Rial Omani
SAOC:	Oman Water and Procurement Company
Scf:	Standard Cubic Foot
SGRF:	State Generated Reserve Fund of Oman
SQU:	Sultan Qaboos University
Tcf:	Trillion Cubic Feet
TRC:	The Research Council of Oman
UN:	United Nations
WB:	World Bank
WCED:	World Commission on Environment and Development
Wh/m2:	Watt Hour Per Square Meter

Map of Oman



Chapter 1

Introduction

“We spend energy to extract energy. Oman’s oil reserves to last for the next 15 years. Thinking about alternative energy is inevitable. Alternative energy could complement oil in supporting the Sultanate’s development at different levels” Omani Undersecretary for the Ministry of Oil and Gas HE Salem Nasser Al Auf criticizing oil production is not sustainable and could deplete in 15 years and alternative energy resources besides other sustainable energy measures should complement energy system in Oman to achieve sustainable development (cited in times of Oman, 2017).¹

1.1 Introduction

Energy diversification is a crucially important but difficult goal for countries around the world, especially those in the Middle East whose national economies depend heavily on oil and gas revenues, such as the Sultanate of Oman. The revenues generated from the oil and gas sector in Oman are the main source of funds for its socioeconomic developments plans, with no contribution from renewable or alternative energy sources thus far, except a pilot project by Petroleum Development Oman (PDO) to use solar energy for the purpose of oil extraction.

The exploitation of oil and gas resources in Gulf Cooperation Council (GCC) countries has rightly raised great levels of concern. The point of peak oil, an estimated time at which the maximum rate of oil extraction is reached, has already passed and the sustainability of supply is a serious concern. Researchers have estimated that in less than two decades, some GCC countries will have already exhausted their fossil fuel resources, including Oman. As a result, renewable energy resources, particularly solar and wind, have gained more interest with the aim to alleviate dependency on non-renewable supplies and enhance economic development.

Energy policy plays a crucial role in securing economic achievements and shifting towards more sustainable energy practices. That is to say, energy policy is not just for ensuring continued supply by balancing supply and demand, but rather it is needed to encourage the production and use of energy resources in ways that sustain resources to promote long-term quality of life and to encourage diversification of energy resources away from depletable oil

¹ Times of Oman (2017). We have oil to last for 15 years, says Ministry Undersecretary in Oman. [online] Available at: <https://timesofoman.com/article/104060> [Accessed 16 Sep. 2017].

and gas resources.²El-Katiri (2013)³ cautions that the high domestic energy demand in all GCC countries, including Oman, to which an increasing proportion of traditional fuel types are being assigned, could affect their status as the main energy exporters to the rest of the world. The marked increases in local energy demand are partly attributed to subsidised energy prices that are much lower than international prices. Notably, the exhaustion of fossil fuel reserves is being accelerated by the Omani government's efforts to address the increasing local energy demand while maintaining export levels. These attempts will ultimately have adverse effects not only on Oman's socioeconomic development, but also on energy sustainability.

The aim of this study is to empirically examine the role of energy diversification policy in achieving energy sustainability in oil-exporting countries, using the example of Oman. This research will uniquely add to the literature by highlighting the key energy measures that can encourage the use of more sustainable energy sources as well as policy measures that can lead to achieving sustainable development.

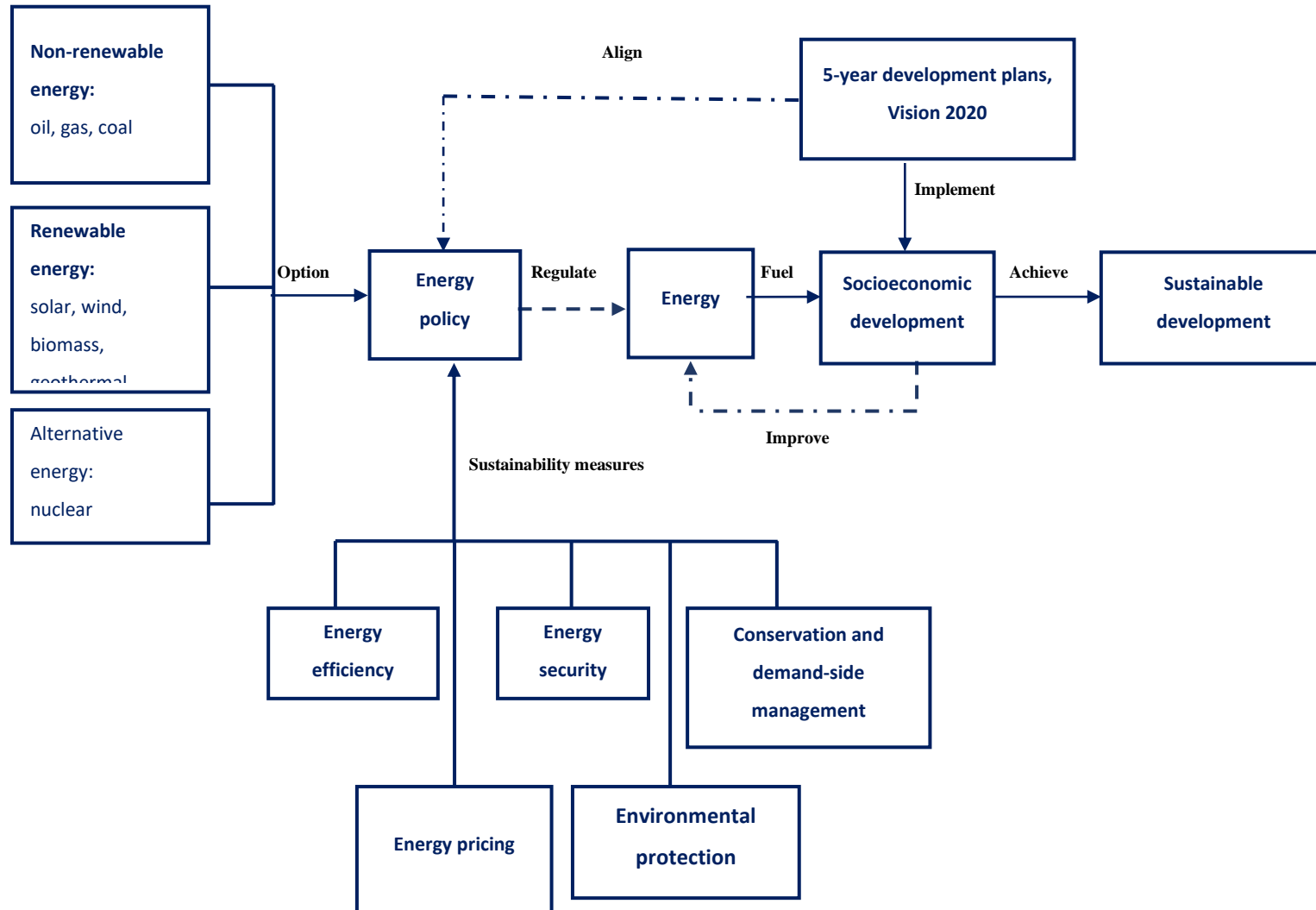
The fundamental objective of any energy sector is to achieve sustainable development (Figure 1-1). Two key methods can be used to achieve sustainable development in developing countries such as Oman.⁴ First, planning policies for socioeconomic development through 5-year development plans and Vision 2020, which is the current economic-diversification strategy that Oman adopts. The second method for achieving sustainable development is through aligning socioeconomic strategy with sustainable energy policy, which is particularly appropriate to oil-exporting countries because they do not currently do this. In Oman, the government is largely responsible for regulating socioeconomic development strategy; thus, the main contributor in achieving sustainable development alongside socioeconomic development is sustainable energy policy put in place by the government.

² Pearson, P. and Watson, J., 2012. UK Energy Policy 1980-2010: A history and lessons to be learnt.

³ El-Katiri, L., 2013. Energy sustainability in the Gulf States: the why and the how. *Oxford Institute for Energy Studies*, http://www.oxfordenergy.org/wpcms/wp-content/uploads/2013/03/MEP_4.pdf, (accessed January 21, 2014).

⁴ Kaygusuz, K., 2012. Energy for sustainable development: A case of developing countries. *Renewable and Sustainable Energy Reviews*, 16(2), pp.1116-1126.

Figure 1- 1: General framework: energy policy and sustainable development



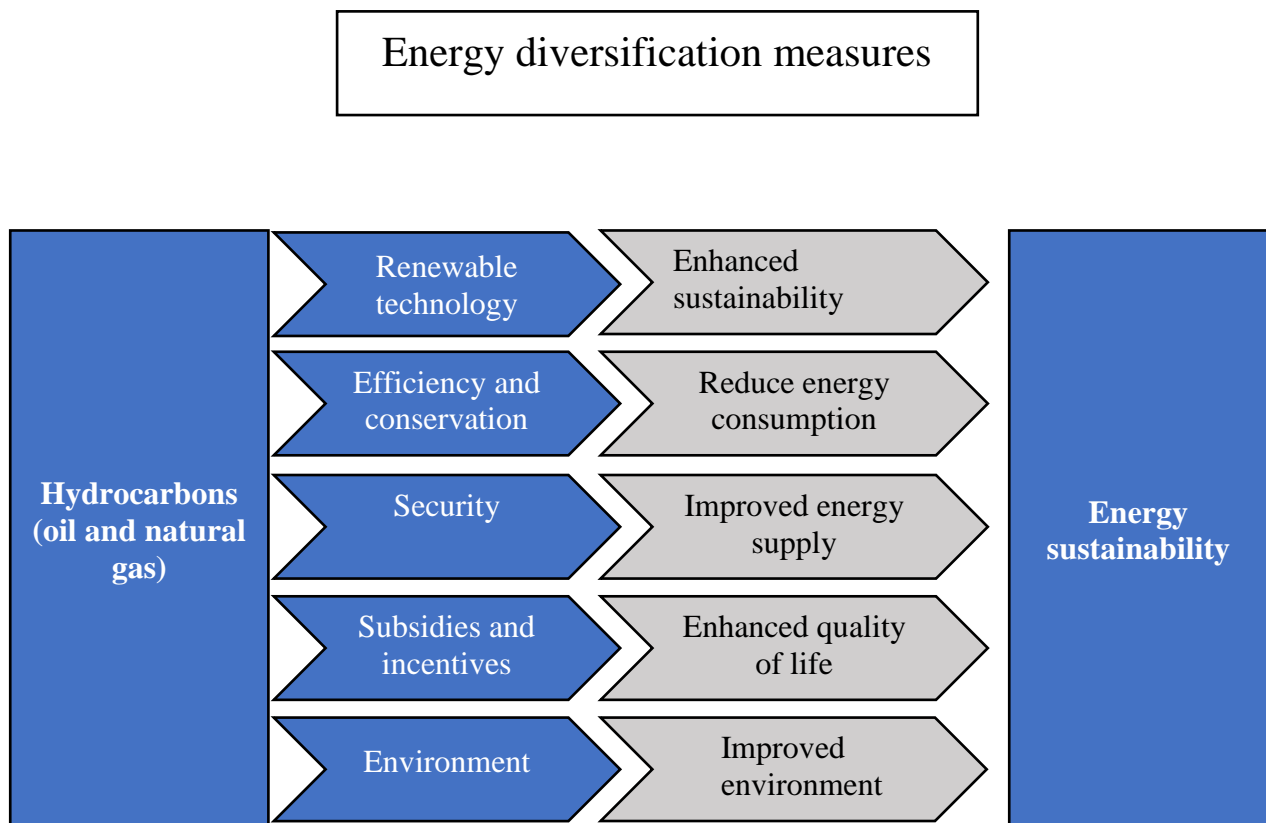
Source: Compiled by the author

1.2 Research aims and objectives

The principle aim of this study is to examine the role of energy diversification in enhancing Oman's national energy policy to achieve sustainability and to identify the potential benefits of renewable energy resources in the energy sector through policies and strategies, technology choices, and laws and regulations. In doing so, the specific objectives of the study are as follows:

- Understand the effect of energy diversification in enhancing Oman's national energy policy by focusing on assessing the effect of renewable energy resources on the energy sector.
- Analyse the effectiveness of national energy policy and the performance of 5-year development plans and Vision 2020 in achieving more sustainability.
- Establish the rules and regulations that are needed to enhance the efficiency and conservation of energy usage.

Figure 1- 2: Energy diversification measures



Source: Compiled by the author

1.3 Research questions

The central aim of this study is to examine the role of energy diversification in enhancing the national energy policy of Oman to achieve sustainability. The main research question is as follows:

“What is the role of energy diversification policy in enhancing energy policy in Oman to achieve sustainable development?”

Three subquestions were used to guide respondents in answering the main research question as follows:

- What factors affect the importance of energy diversification for oil and gas-exporting countries to achieve sustainability?
- Do renewable energy resources reduce the heavy reliance of the energy sector on oil and gas?
- What energy sustainability measures are needed to enhance efficiency of energy use and conservation of energy resources?

1.4 Research significance and contribution

This study will contribute to the debate on energy diversification and sustainability on several levels. First, most practical and theoretical research on using energy diversification to enhance sustainability of a country’s energy sector has been done in developed countries. However, less attention has been paid to energy diversification in developing countries, or specifically in oil-exporting countries. This study, to the best of the researcher’s knowledge, is the first to analyse the interaction of energy diversification policy and national energy policy in Oman. This research identifies the factors that influence the national energy policy of Oman in terms of sustainability and energy diversification.

Second, oil and natural gas resources are estimated to be entirely depleted in Oman within two decades if current oil and gas extraction rates continue, which puts the government under great pressure to find other sources of income that reduce the heavy dependency on these natural resources. Besides the problem that they rely on a limited resource, oil and gas revenues are unsustainable because they are affected by fluctuations and volatility of international oil prices,

and also by the risk of export demand being replaced by other sources of energy. Therefore, sustaining the economic level of development in Oman that has been achieved during the past 40 years requires the expansion of energy policy into the field of renewable energy resources and energy demand side.

Third, this study aims to examine the 5-year development plans and Vision 2020 in Oman to identify the reasons underlying their failure to increase energy diversification to improve sustainability. Given the sparse clear oil and gas policy measures in Vision 2020, this study aims to provide guidance for future development plans to introduce clear policy measures and targets toward more sustainable sources of energy to reduce the reliance on the oil revenues.

Fourth, this study will raise awareness not only among decision makers in the government, but also among oil and gas companies in Oman, regarding the potential and feasibility of using new resources to finance the economic transition process. The study will focus on renewable energy initiatives and sustainable energy measures, and how to make sustainable energy choices that could impact positively on Oman's current national energy policy and tackle its economic challenges.

Fifth, the results of this study can potentially be applied to other similar oil-exporting countries, such as the GCC countries, providing widespread application and diversification opportunities.

Sixth, this research contributes to sustainable development theory by empirically studying how energy sustainability measures perform in the energy sectors of these types of countries.

Seventh, this study will provide new information on the effect of energy sustainability policy at the country level, in Oman.

Eighth, the methods used in this study uniquely contribute to the literature because for the first time, a qualitative method is used to assess energy sustainability measures in Oman.

1.5 Research design and methodology

To date, little or no previous studies have assessed energy diversification policy, from Oman's perspective, and thus, scarce accurate, timely, and reliable data are available. To obtain these data, this study will use semi-structured interviews with key energy sector stakeholders and secondary data sources such as official statistics and documents from the government of Oman. Interviews enable the analysis of different experiences and views of respondents in the energy decision-making process. Results can be used to benefit the energy sector in general and in terms of energy diversification policy.

One aspect of this research was explorative, involving developing new documented evidence for a subject with little literature. Semi-structured interviews allow informants the flexibility to express their views in their own terms, while maintaining a general core of questions so that their answers could be compared with other respondents. Collecting data from secondary sources prevents the duplication of efforts and saves time and cost resources.

1.6 Semi-structured interviews

Fieldwork was done between May and August, 2015, including face-to-face interviews with 25 participants from three sectors: public, private, and academic. The interviewees, in most cases, were in senior positions among their company or field. The snowball technique was used to identify participants, by which the first interviewee is asked to help identify other relevant individuals that could be interviewed. Inclusion criteria were that an interviewee had either influence over, or expertise in, Oman's energy sector. All interviews were documented and voice recorded.

The main themes of the interviews were theoretical concepts of energy and sustainability policy, energy conservation and efficiency, renewable resources, and other aspects that are essential for energy diversification. Additionally, the interviews provided a clear understanding of decision-makers' expectations and perceptions of the Omani energy sector, which can offer more value-added information than secondary data resources. The interviews were therefore additionally used to explore and reflect on the finding from secondary data analysis.

1.7 Secondary data sources

The secondary data sources were internal (official Omani publications) and external (sources outside the GCC). Secondary data collected from Oman were as follows: (1) the National Research Strategy issued by The Research Council; (2) the annual statistical yearbook published by the National Centre for Statistics and Information; (3) the annual report issued by the Ministry of Oil and Gas; (4) the annual report published by the Central Bank of Oman; and (5) the annual report published by the Secretariat of Cooperation Council for the Arab States of the Gulf. External secondary sources of information are those issued by international organisations, including but not limited to the following: (1) the annual report issued by the International Energy Agency; (2) the annual report issued by the US Energy Information Administration; (3) the annual report issued by the United Nations; (4) the annual report issued by the International Renewable Energy Agency; (5) the annual report issued by the International Atomic Energy Agency; (6) the annual report published by the Arab Atomic Energy Agency; and (7) the World Development Report issued by the World Bank. Data was also collected from on-shelf and online sources such as articles, journals, books, reports, and publications.

1.8 Scope of the research

This study examines the role of energy diversification of national energy policy in Oman through the lens of sustainable development theory specifically in the energy sector (i.e., not in terms of social progress, environmental progressions, or economic growth dimensions). Although this study highlights the importance of relationships between the energy sector and the economic, social, and environmental dimensions of sustainable development,⁵ the main focus is the effect of diversification of energy resources on national energy policy, specifically assessing energy sustainability and the potential of renewable resources, efficiency and conservation, energy demand, security, subsidies and incentives, and environmental protection in an oil-exporting country, with a specific focus on Oman.

⁵ Rosen, M.A. and Dincer, I., 2001. Exergy as the confluence of energy, environment and sustainable development. *Exergy, an International journal*, 1(1), pp.3-13.

In 1987, the World Commission on Environment and Development (WCED) published the Brundtland report, which defined sustainable development as “development that meets the needs of the present generations without compromising the ability of future generations to meet their own needs” (WCED, 1987). Since the Brundtland report, sustainable development has been implemented worldwide by many governments, organisations, and individuals. The diversification of Oman’s energy base by examining energy policy framework towards more renewable energy types and improved energy sustainability practices would reduce its reliance on depletable energy resources, expanding the lifespan of these resources to meet the needs of future generations.

The scope of the research in this study was carefully defined to ensure efforts are focused as well as to make the study possible. However, it is important to clarify the distinction between the three terms of energy diversification, energy sustainability, and economic diversification, which are used throughout this study. The energy diversification, as defined in the literature, means using different energy sources to reduce dependence on a single resource and it’s important for an energy system’s long-term survival, which helps achieving the ultimate goal of energy sustainability⁶. Economic diversification means the process of shifting an economy away from an oil-based economy to non-oil-based economy. In this thesis, however, economic diversification (diversification of a country’s sources of revenues) does not necessarily equate diversification of a country’s sources of energy. In other words, economic diversification can take place without any progress in terms of energy sustainability. In addition, energy sustainability and sustainable development terms are used interchangeably for the purpose of this research study.

1.9 Rationale for selection of Oman as a case study

In this study, the example of Oman is used because it has undergone a rapid economic development over the past 50 years. Since oil discoveries were made in 1962 and the first commercial shipment of Omani oil was exported in 1967,⁷ Oman has become an oil-exporting country, using profits from this sector to push the country through rapid socioeconomic

⁶ Ranjan, A. and Hughes, L., 2014. Energy security and the diversity of energy flows in an energy system. *Energy*, 73, pp.137-144.

⁷ Al-Ismaïly, H.A. and Probert, S.D., 1997. Energy overview for the sultanate of Oman. *Applied energy*, 57(4), pp.287-325.

development. However, over the past 15 years, these gains have been threatened by the realisation of diminishing oil reserves, and a decline in the rate of oil production as well as shrinking revenues from oil sales have resulted from increasingly costly and complex extraction methods being required.

Although Oman is classified by the UN as having a high-income country, it remains a developing country.⁸ To achieve a developed country status, industrialisation and economic diversification are required so that Oman no longer relies on the extraction of its limited oil and gas reserves. However, this development needs to be sustainable in terms of balancing energy demand with supply. The first step toward this sustainable development is national energy policy.

Within the Sultanate of Oman, there are nine administrative regions: Muscat (the capital), Al-Dakhliya, Dhofar, Al-Buraymi, Musandam, Al-Wustam, Al-Sharqia, Al-Batinah, and Al-Dhahirah.⁹ Each region consists of many smaller subregions called Willyaih, and each Willyaih consists of many small and scattered villages. Huge costs are involved in providing electricity to all these geographically scattered areas and connecting them to the main grid.

Oman's climate varies across the country. During the summer in coastal areas, temperatures are high (up to 45°C) and the atmosphere is humid, especially in June. In the inland parts of Oman, the climate is generally hot and dry, except in the more moderate mountainous areas. The location and climate of Oman are complementary to various types of renewable energy. For example, Oman's solar resources are considered among the highest in the world.¹⁰ According to a study by the Authorities for Electricity Regulation in Oman, "wind and solar energy have the potential to provide sufficient electricity to meet all of Oman's domestic

⁸ UN, 2014. Country Classification System, Country classification - Data sources, country classifications and aggregation methodology. doi:http://web.worldbank.org/WBSITE/EXTERNAL/DATASTATISTICS/0,,contentMDK:20421402~pagePK:64133150~piPK:64133175~theSitePK:239419,00.html#Low_income (Accessed February 5, 2007)

⁹ NCSI (2006) Statistical yearbook. Muscat: National Centre for Statistics and Information.

¹⁰ Al-Badi, A.H., Malik, A. and Gastli, A., 2009. Assessment of renewable energy resources potential in Oman and identification of barrier to their significant utilization. *Renewable and Sustainable Energy Reviews*, 13(9), pp.2734-2739.

electricity requirements and provide some electricity for export”.¹¹ The average number of days of clear sky per year in Oman is about 342 in all regions,¹² and solar strength rapidly increases during the summer time, which is the time of peak electricity demand in Oman. Furthermore, because of the location of Oman and the length of its coastline, wind energy is also a feasible option. This renewable energy potential has the potential to reduce the volatility of the economy and address environmental concerns.¹³ Potential renewable energy resources and sustainable energy measures in Oman are discussed in detail in a later section.

1.10 Population

Population statistics describe the characteristics and behaviour of a population, including its size, growth, structure, and geographic distribution, and the elements that drive population changes (births, deaths, and immigration).¹⁴ Population statistics in themselves do not reflect the indicators of sustainable wellbeing, but they highlight a variety of issues such as labour, ageing, and population sustainability.

However, the main population concern is not about the number of people per se, but rather the level of consumption of natural resources. More people means more demands are placed on natural resources such as food, fresh water, minerals, and most importantly, energy. Therefore, although many elements can contribute to increasing sustainable development, the most important element is the need to provide sustainable energy.

The population of Oman is changing rapidly in terms of size and distribution. According to the World Bank, Oman’s population was 0.6 million in 1960 and estimated at 3.8 million in 2014; in other words, it experienced a five-fold increase over 50 years.¹⁵ The main reason for this

¹¹ Authority for Electricity Regulation, Oman (2008). Study on Renewable Energy Resources, Oman Final Report. [online] Muscat. Available at: http://regulationbodyofknowledge.org/wp-content/uploads/2013/09/AuthorityforElectricityRegulation_Oman_Study_on.pdf [Accessed 4 Sep. 2018].

¹² Al Hatmi, Y. and Tan, C.S., 2013. Issues and challenges with renewable energy in Oman. *Gas (BCM)*, 4(9), pp.212-218.

¹³ Dincer, I., 2000. Renewable energy and sustainable development: a crucial review. *Renewable and sustainable energy reviews*, 4(2), pp.157-175.

¹⁴ Office for national statistics [online]. Available from: <http://www.ons.gov.uk/ons/guide-method/method-quality/specific/population-and-migration/an-overview-of-ons-s-population-statistics/index.html>

¹⁵ The WB (2017) World bank indicators [online]. Available from: <http://data.worldbank.org/country/oman>

increase in population size is the rapid development that Oman witnessed after the arrival of the modern Renaissance in 1971, which resulted in upgraded infrastructure, improved economic development, improved per capita income, improved health and education, and a larger labour market. These advances have also resulted in the return of many expatriate Omanis who had left the country to work in other countries.¹⁶

The official source of data on Oman's population is the actual results of a general census of the population, which usually takes place every 10 years.¹⁷ The Sultanate of Oman did the first population census in 1993, when the population stood at 2,018,074 (including Omanis and non-Omanis), and the latest population census was in 2010, with 2,773,479 people.¹⁸ This means that the total population has increased by about a third in the past decade. Simultaneously, a substantial increase in energy demand (electricity) has occurred, which comes not only from the overall increase in the Omani population (about 50% of electricity consumption is domestic use), but also from expansion in various sectors of the economy, such as industry, tourism, energy, and transportation. Therefore, one of the options that will be investigated later from the energy policy view is energy saving and conservation in tackling the issue of matching energy supply with demand.

The growth rate of Oman's population has increased significantly because of the high birth rate and because of the inflow of non-Omani immigrants working in Oman.¹⁹ Energy production is also greatly increasing to cope with the socioeconomic development of the country. However, this increase in energy consumption is generated from unsustainable fossil fuel resources, leaving less fossil fuel resources for export, reducing income from this source. Therefore, Oman should pay special attention to renewable energy resources as well as to sustainable energy measures, which are able to meet present and future energy demands.

¹⁶ Al-Busaidi, M., 2012. *The struggle between nature and development: Linking local knowledge with sustainable natural resources management in Al-Jabal Al-Akhdar Region, Oman* (Doctoral dissertation, University of Glasgow).

¹⁷ NCSI (2012) Statistical yearbook. Muscat: National Centre for Statistics and Information.

¹⁸ Before 1993 no accurate information exists about figures and related statistics, estimations were only provided by the ministry of national economy.

¹⁹ Since the discovery of Oman oil in 1960s, many expatriates participate in the development process of the national economy as well as the last ten years the industry sector is booming and that required the use of external expertise which made the number of the population to increase significantly.

As shown in table 1-1, about 56% of the population of Oman in 2018 were Omanis and 44% were non-Omanis (foreign workers and their families).²⁰ The Al Batinah region has the largest proportion of the Omani population of any region (about 31%), followed by Muscat. By contrast, Muscat is the region with the highest proportion of the non-Omani population of Oman (about 45%). Muscat is also the region with the greatest proportion of non-Omani to Omanis, with 63.7% non-Omanis to 36.2% Omani nationals, whereas Al Dakhliyah has the smallest proportion, with 25.4% non-Omanis to 74.5% Omani nationals.

Table 1- 1: Total population registered in Oman by nationality and region in year 2018

Region	Omani Nationality	Non-Omani	Total
Muscat	528,327 (36.2%)	930,922 (63.7%)	1,459,249
Dhofar	210,984 (46.4%)	246,638 (53.5%)	454,622
Musandam	28,477 (63.8%)	16,094 (36.1%)	44,571
Al Buraymi	54,818 (47.9%)	59,516 (52%)	114,334
Al Dakhliyah	343,712 (74.5%)	117,487 (25.4%)	461,199
Al Batinah	788,981 (67.3%)	383,035 (32.6%)	1,172,016
Al Sharqiyah	374,896 (63.1%)	217,149 (36.8%)	592,045
Al Dhahira	151,308 (70.7%)	62,463 (29.2%)	213,771
Al Wusta	23,688 (52.8%)	21,290 (47.1%)	45,156
Total	2,505,191 (56.3%)	2,054,594 (43.7%)	4,559,785

Source: Statistical year book (2018), National Centre for Statistics and Information. Percentages show proportions of Omanis and non-Omanis in each region's total population.

Most immigrants to Oman come to work in the industries focused on development of Oman's infrastructure. The large influx of non-Omanis has partly allowed the swift improvement in the health and education of the population, reduction of poverty, an increase in productive capacity, and rising per capita income.

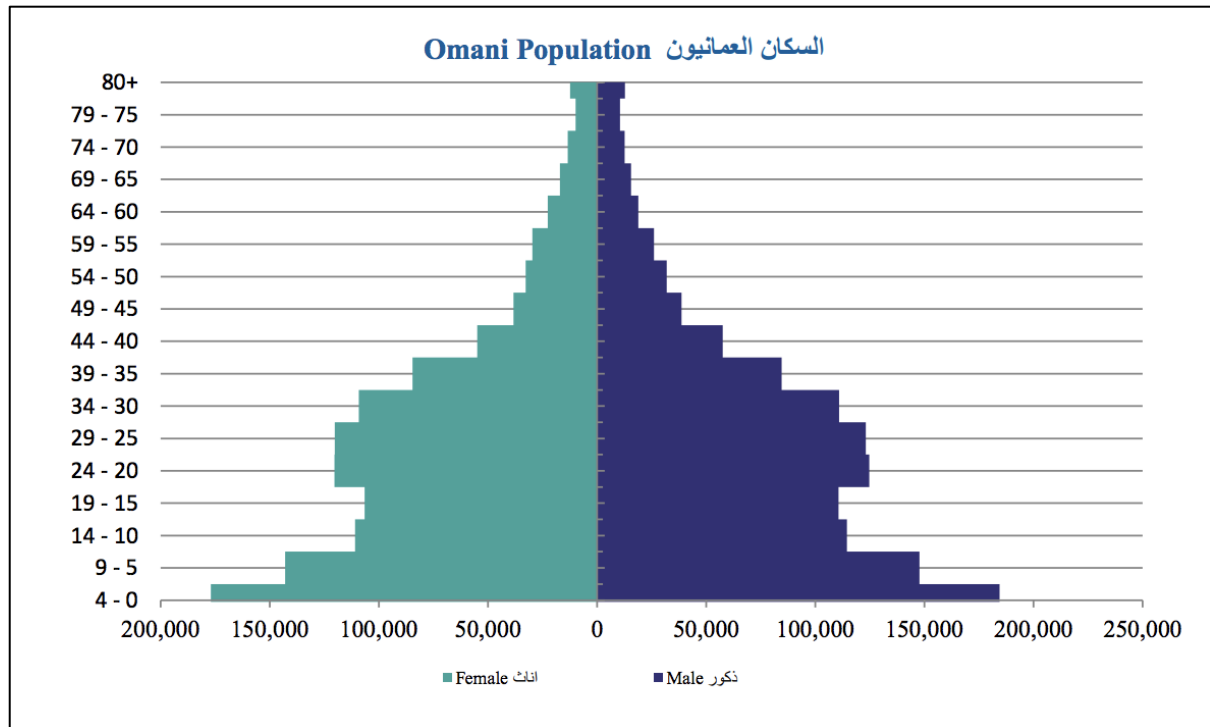
According to the 1993 population census, men represented 48% of the Omani population, equating to 968,975 people. More than a half of the Omani population (about 52%) was younger than 20 years old, just less than half (about 45%) were aged between 20 and 64 years old, and the remainder (3%) were older than 64 years.²¹ This spread of age demographics means that in the near future, as the younger generation reaches adulthood, a sharp increase in

²⁰ NCSI (2018) Statistical yearbook. Muscat: National Centre for Statistics and Information.

²¹ MONE (1993a) Statistical yearbook. Muscat: Ministry of National Economy.

electrical energy consumption is to be expected because of the large increase in the number of houses, volume of traffic, and development of industrial and manufacturing businesses.

Figure 1- 3: The female and male Omani population by age group, 2017

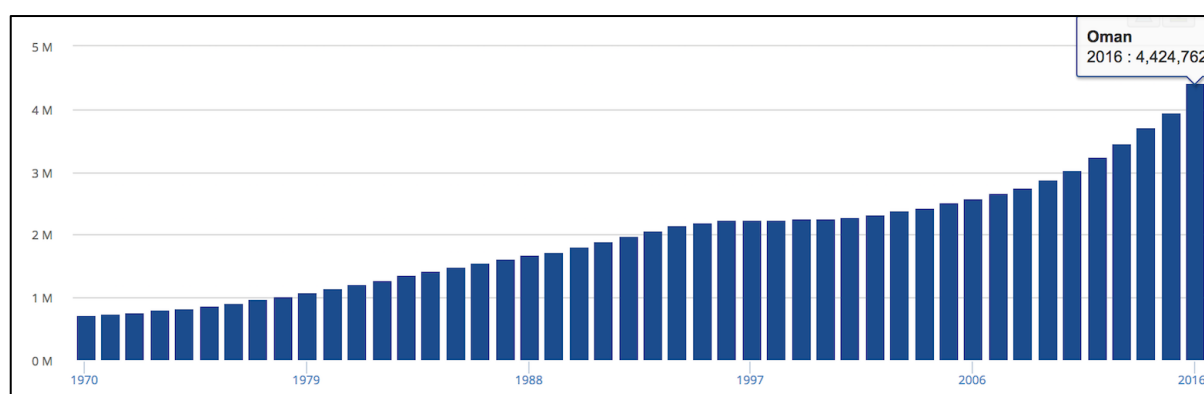


Source: Statistical year book (2017), National Centre for Statistics and Information

According to the 2010 census, women made up about half of the Omani population (49%). About 57% of the Omani population were younger than 20 years, about 38% were aged 20–64 years and the remaining 5% were older than 64 (Figure 1-3).²²

²² NCSI (2014) Statistical yearbook. Muscat: National Centre for Statistics and Information.

Figure 1- 4: Population growth in Oman, 1970-2016



Source: Compiled by the author, data obtained from the World Bank 2018

Between 1985 and 2002, the population of Oman increased 3.6% per year on average (Figure 1-2). After 2002, the population growth rate decreased to 2.3% per year as a result of advanced health services, better education, and public awareness of the need to slow the increase in population size.

Because most Omani nationals are younger than 20 years (about 57%), about 1,115,680 citizens will enter the workforce over the next 18 years. According to the International Labour Organization, the economically active population was 53% of working age men in 2011, which was the highest rate for the past 21 years, with the lowest rate being 46% in 1996. However, for women the rate was much lower, with 24.2% in 2011 and the lowest rate was 1995, with 18.7%.²³

1.11 Labour force

The labour force in Oman accounted for 47.3% of the total population (3,855,206) in 2014.²⁴ Non-Omanis account for 78.6% of this total workforce, whereas Omanis account for 21.4% (table 1-2). The main reason behind this wide gap is the ratio (almost 5:1) of men to women in the non-Omani community, given the fact that most non-Omani workers are single men.²⁵

²³ ILO (2016) International Labour Organization [online]. Available from: www.ilo.org/global/lang-en/index.htm.

²⁴ NCSI (2014) Statistical yearbook. Muscat: National Centre for Statistics and Information.

²⁵ Ibid

Table 1- 2: Distribution of labour force by economic sector within Oman in 2014

Economic sector	Omani nationals	Non-Omani	Total
Government sector	165,219 (56.5%)	127,193 (43.5%)	292,412
Brokerage	15,173 (80.6%)	3,648 (19.4%)	18,821
Electricity, gas, and water supply	2,216 (74.6%)	753 (25.4%)	2,969
Mining and quarrying	23,375 (59.0%)	16,214 (41.0%)	39,589
Transport, storage, and communication	13,547 (29.6%)	32,152 (70.4%)	45,699
Education	5,054 (28.1%)	12,932 (71.9%)	17,986
Public administration, defence, and social security	34 (25.6%)	99 (74.4%)	133
Real estate and rental	20,616 (24.4%)	63,765 (75.6%)	84,381
Wholesale and retail trade	35,068 (16.1%)	182,817 (83.9%)	217,885
Health and social work	1,285 (15.0%)	7,297 (85.0%)	8,582
Agriculture	1,566 (13.4%)	10,123 (86.6%)	11,689
Fishing	47 (11.3%)	368 (88.7%)	415
Manufacturing	22,078 (10.8%)	182,128 (89.2%)	204,206
Construction	76,121 (10.2%)	671,163 (89.8%)	747,284
Hotels and restaurants	7,227 (7.5%)	89,376 (92.5%)	96,603
Community and personal services activities	1,286 (3.4%)	36,146 (96.6%)	37,432
Private households and appoint members	3 (100%)	0	3
Organisations and regional bodies	2 (100%)	0	2
Total	389,917 (21.4%)	1,436,174 (78.6%)	1,826,091

Source: Statistical year book (2014), National Centre for Statistics and Information. Percentages show proportion of Omanis and non-Omanis in each sector's labour force.

The government sector employs more than half of Omani nationals, which is by far the largest proportion of Omanis employed by one sector (table 1-2). By contrast, the construction sector is the biggest employer for non-Omanis; and about 90% of the labour force in the construction sector consists of non-Omani workers.

1.12 Economy

The strategic geographic location of Oman plays a pivotal role in its economy. Oman has benefited from a long history of trade with many countries around the world such as China, India, Iran, Egypt, and those along the old frankincense and silk routes.²⁶ Omani ships and caravans carried indigenous goods, including dates, limes, and frankincense, around the world while strengthening ties and exchanging culture between countries.

Oil was first discovered in Oman in 1962 and was exploited on a commercial scale from 1967 onwards. Before that, the Omani economy was heavily dependent on agriculture and fisheries. In 1965, these sectors accounted for 61% of gross domestic product (GDP), industry contributed 23%, and services contributed 16%.²⁷ By 1970, the share of oil revenue in GDP was about 70%, which gradually decreased to 46% by 2010.²⁸

In 1975, the Omani government formulated a development strategy for the subsequent 25 years, starting the implementation phase in 1976 with four 5-year development plans. In the early 1970s when the HM Sultan Qaboos came to power, the main challenge that the government faced was poor general infrastructure and absence of modern facilities and institutions. According to Calvin and Allen, Oman had a huge need for almost everything. New infrastructure was needed, including roads, communication, financial services, water resources, and housing, given the high expectation that the new ruler would transform the country quickly.²⁹ The nominal GDP in 1970 was about US\$260 million, which had markedly

²⁶ MOI (2013) Oman Book. Muscat: Ministry of information.

²⁷ Al-Yousef, M.B.M., 1997. *The state and market in Oman's development: conflict or cooperation?* (Doctoral dissertation, University of London).

²⁸ MONE (2011) Statistical yearbook. Muscat: Ministry of National Economy.

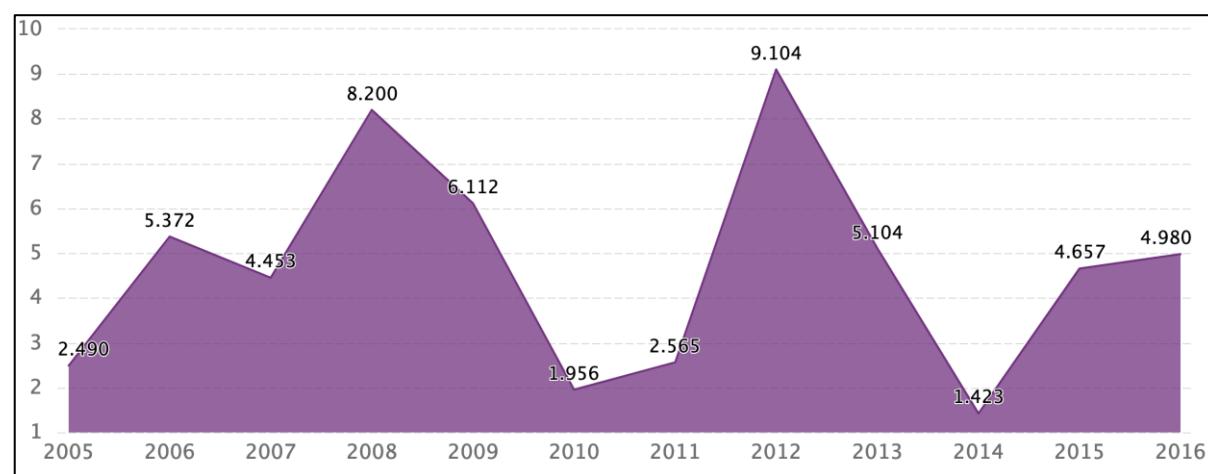
²⁹ Allen Jr, C.H., 2016. *Oman: the modernization of the sultanate*. Routledge.

increased to \$69.97 billion by 2011.³⁰ These achievements have been reflected positively in social, environmental, economic, and political development, as well as overall stability. During the past four decades Oman has achieved rapid developmental progress. Alongside the economic development of the country, a cultural transformation and better standard of living has been created in Oman. Before 1970, Oman was categorised as one of the poorest countries of the world, yet it is now categorised as a high-income non-OECD state.

The exploration of oil was the main driver behind the growth of the Omani economy and the country's prosperity. The rapid increase of oil revenues allowed the government not only to invest in general infrastructure, transportation, health, and education, but also to provide free education and medical care for people without taxing their income, and subsidies to the energy sector, while also keeping inflation low.

Oman now has one of the highest GDP growth rates in the Middle East and North Africa (MENA) region, averaging 5.38% annually between 2000 and 2013, despite the rapid growth rate of the population.³¹ In 2000, Oman's per capita income was \$7,360, which rose to \$22,181 in 2013 (Figure 1-5).³²

Figure 1- 5: Annual GDP growth rate (%), Oman 2005–16



Source: Trading Economics, 2017

³⁰ The WB (2017) World bank indicators [online]. Available from: <http://data.worldbank.org/country/oman>

³¹ Trading Economics (2015) [online]. Available from: www.tradingeconomics.com

³² The WB (2013) World bank indicators [online]. Available from: <http://data.worldbank.org/country/oman>

However, through the process of socioeconomic development over the past 40 years,³³ Oman has had four major economic shocks. The first was when oil prices declined in 1986. The global oil price decreased sharply from US\$27 per barrel in 1985 to US\$13 per barrel in 1986, resulting in a –12.5% change in GDP.³⁴ This 1986 oil price drop was the first time that attention was drawn to the vulnerability of Oman's economy and reliance on oil income. The shock resulted in substantial reductions in revenue, and put the government in a large fiscal deficit.³⁵

In 1998, the second economic shock happened when international oil prices declined from US\$19 to US\$12 per barrel, resulting in a significant drop in oil export revenues and a –11% change in total GDP. The Omani government had to strike a careful balance between repaying the large fiscal deficit—more than US\$5 billion of local and foreign debt—and maintaining the same level of socioeconomic development.

Both these shocks highlighted the vulnerability of the Omani economy to even a slight change in oil prices. The government had to liquidate its external investments, cut costs in various sectors, and defer new projects to overcome the effects of these fluctuations, confirming that the Omani economy depends too heavily on its oil revenues.³⁶ Thus, diversification to other types of income is vital to help stabilise Oman's economy and prepare for future oil shocks.

In order to maintain positive economic growth and overcome the challenges faced following the oil price drops, the Omani government asked the World Bank and the International Monetary Fund (IMF) for technical help. The main goal was to develop a strategy for a more diversified source of income that could strengthen oil-related industries as well as enhance the oil and gas export capacities.³⁷

Furthermore, the strategy aimed to strengthen the social and economic sectors by investing in service industries such as tourism, insurance, trade, financial services, health care, and education as the main core of the economic development strategy. This strategy, known as Vision 2020 (1996–2020), aimed to transform the country from being an oil-based economy to

³³ Five- year development plans were launched from the period of 1976-1995 to set the economic base of the country and to invest the exporting oil revenues in economic and social infrastructure.

³⁴ NCSI (2004) Statistical yearbook. Muscat: National Centre for Statistics and Information.

³⁵ Ibid

³⁶ MONE (2006) Statistical yearbook. Muscat: Ministry of National Economy.

³⁷ CBO (2005) Annual report. Muscat: Central Bank of Oman.

a more diversified economy, by increasing private initiatives, employment of Omani nationals, and using renewable resources.³⁸

Although the economy remains heavily dependent on oil revenues, policy makers have given special attention to establishing suitable conditions for investment by providing the right infrastructure to accommodate business activities and develop the national workforce. However, some challenges are still faced by the Omani economy, as highlighted by a report from the UN's Economic and Social Commission for Western Asia report:³⁹

- Oman depends too much on exports of crude oil and other hydrocarbons
- The private sector is too small
- The economy has risen to a moderate status solely because of oil revenues
- Use of natural resources other than hydrocarbons is scarce
- Few Omanis work in the private sector because the government sector is more stable. This prevents private sector expansion

Vision 2020 aims to overcome these challenges and focuses on a set of core economic strategies designed to diversify sources of national income by improving various sectors of the economy such as tourism, energy, mining, and commerce,⁴⁰ as will be analysed in later sections.

1.13 Structure of the thesis

In order to achieve the research aims and objectives, the thesis consists of eight chapters including this introductory chapter, as follow:

Introductory chapter mainly presents an overall background of the research study, research aims and objectives, significance and contribution, questions, methodology adopted, rationale of case selection, scope and limitation, and provides an overview of Oman in terms of population, labor force, and economy.

Chapter two involves a critical review of the literature study relevant to energy diversification to improve sustainability. It first reviews the existing literature of energy diversification from

³⁸ Ministry of National Economy annual report: 2004, Sultanate of Oman.

³⁹ ESCWA (2012) Annual report. UN: Economic and Social Commission for Western Asia.

⁴⁰ MOI (2013) Oman Book. Muscat: Ministry of information [online]. Available from: <http://www.omanet.om/english/home.asp>.

a number of different aspects, in terms of its definitions, origin, and general nature. Then, it provides the context of the pressing need for sustainability as well as its relation to economic, social environment linkages. Chapter two also highlights energy security in terms of supply and demand as well as energy efficiency and conservation. It also provides an overview of challenges and opportunities of renewable and non-renewable energy in oil-exporting countries. Exploring sustainable development literature provides significant information that will benefit resolution of Oman's energy policy as well as overviewing socio-economic challenges from the energy sustainability perspective.

Chapter three develops a conceptual framework that are proposed to guide the data collection and analysis. The conceptual framework suggests four interrelated factors that impact the performance of energy sustainability. These factors are energy policies, domestic energy demand, energy diversification, and environmental protection. This framework helps the implementation of the study and provides the researcher with assumptions about the data collection and analysis process.

Chapter four presents an overview of energy sector and how this sector behaves towards energy sustainability in Oman. The first section provides economy background in relation to energy sector, then discusses Vision 2020 and primary energy supply and consumption as well as government investments in the sector. It also provides an overview of the literature on renewable energy resources, in addition to electricity generation cost.

Chapter five provides a brief overview of the research design and the methodology adopted in the present research. In addition, the chapter discusses its different philosophical assumptions and justifies the analysis techniques adopted, including the sampling and examining through a number of different methods. The research limitations and drawbacks, in addition to certain associated ethical problems, are discussed.

Chapter six and seven provide the findings. Chapter six analyses the semi-structure interviews in relation to economy performance and energy aspects, as well as analyses the development planning policies in each five-year development plan. It then presents an analysis of the Vision 2020 in relation to its objectives, challenges and contradictions.

Chapter seven analyses four particular set of barriers that hinder energy sector to achieving energy sustainability, including: energy policy; domestic energy demand; diversification of energy resources; in addition to environmental protection, are analysed.

Chapter eight summaries this study and presents an overview of the entire study. This chapter providers the contribution of this study to theory and knowledge, the implication for policymaking in relation to government officials, as well as oil companies and the private sector. The implications help decision makers and relevant parties to benefit from the outcomes acquired in order to enhance the performance of energy system and improve energy policies. This chapter also addresses the limitations of this research, which can be identified as opportunities for future researchers to perform further research on this phenomenon from different angle.

1.14 Research Limitations

Literature: Obviously, a research study that focuses on a case study like Oman or any other developing countries is limited. The literature from Oman's energy sector in terms of policies is limited at best case, and unobtainable in many cases, given the fact that no clear technical details of formulation and implementation of policies and plans in the energy sector, which makes it difficult to realize some historical policy aspects.

Energy sector: Oman's energy sector faces some difficulties and there are many causes for this. Some of the many reasons can be attributed from the absence of the national energy policy in place, which could give a clearer direction and trend of the energy development, performance, and behavior towards sustainability. There are some governmental entities that have fragmented plans mainly for closing the gap between energy consumption and production, which does not serve energy sustainability in the long run.

Methodology: The interview was designed for high-profile officials and policymakers, but these individuals do not have much spare time. The procedures for communication with these participants were very slow, and took far more time than expected. This created a clash of appointments on several occasions. This happened when the interviewer received an approval to meet a high-profile official on a day that another meeting was already scheduled, so the

interviewer had to postpone one meeting resulting in an extended wait of four weeks. Thus, there is no planning frame existed from which to consider all alternative options and outcomes when meetings with high-profile officials.

Secondary data: it is very important to have reliable sources in terms of accurate and in-depth information for better analysis. However, some references that were accessed through websites were of limited help; they only provide general information and statistics about the energy sector of the country, this issue is not restricted to Oman, but most of the developing countries. This is also the case for governmental websites. Therefore, these websites were utilized for the collection of contextual information about the energy resources in Oman, the level of energy extraction and consumption, and the challenges these energy resources face, in addition to the significant efforts contributed by different governmental bodies to solve these challenges in the framework of the annual plans.

Chapter 2

Theoretical Perspective and Literature Review on Energy Diversification and Sustainability

2.1 Introduction

The proceeding chapter is a review of the current literature relevant to energy diversification in Oman in terms of renewable and non-renewable energy resources. It provides an overview of energy diversification and the theories of how energy diversification can be implemented, and methods that could be put to use in Oman; then it explores the objectives of energy diversification in terms of energy sustainability perspectives, environmental concerns, energy security, and energy efficiency and conservation. The review identifies the potential of renewable energy resources with the use of new technology. It then discusses oil and gas policies in importing and exporting countries and how they compare with those in Oman. Finally, the global views of energy diversification, and how other countries act upon it—ie, the political dimension—are evaluated.

There are two main objectives in this literature review: to define the reasons for the present study and to identify knowledge gaps in present literature that need further research. Notably, very few previous studies have examined energy diversification, especially in Oman. Oman has been slow in the development of energy-mix resources and has poor energy sustainability, but the diversification of energy resources is predicted not only to significantly enhance the sustainability of national energy policy, but improve the energy performance so that resources last longer. Diversification is also predicted to influence the rules and regulations that are needed to promote efficiency and conservation, which have not yet been subjected to scientific investigation. For example, energy diversification is heavily based on the experience of industrialised countries because this is where most research has been conducted. Only recently have developing countries begun to show an interest in energy diversification to achieve sustainability, and no studies have yet been done in the Middle East or North Africa regions, including Oman.

To identify relevant studies for the present review, highly cited articles were carefully chosen when possible. The references in the identified articles were then selectively checked in a snowballing process. Because of the low availability of studies, the present literature review focuses mostly on studies that discuss the diversity of energy resources in developed countries, which can then ideally be applied to developing countries.

2.2 The objectives of energy diversification resources

The term diversification has been widely discussed within different disciplines, including economics, social sciences, and environmental sciences, and they all have created complex frameworks for analysing diversification in different contexts.⁴¹ Therefore, the analysis of energy diversification can build upon on these processes established in other fields.

Diversity is treated by many stakeholders, including researchers and policymakers, as crucial for an energy system's long-term survival.⁴² According to Stirling, diversity has four main advantages: (1) it is the key to increasing innovation and growth; (2) it is a means by which to hedge against uncertainty and ignorance in decision making, which are both common in renewable energy policymaking; (3) it can minimise negative effects such as supply shocks and lock-in (ie, getting stuck with one source of energy); (4) it is a method of adapting values and interests that exist in a society—eg, the choice to turn off lights that are not needed, or to use the bus instead of a car. In addition, diversity can also help energy systems efficiently adapt to external changes such as energy disruption (eg, trade disputes, embargoes, and political instabilities), changes in regulations related to technologies and the environment, or price changes for a specific energy commodity.⁴³

2.2.1 The need for energy sustainability

Demand for energy is increasing around the world, with global energy consumption predicted to rise by at least a third between 2010 and 2040. Figure 2-1 shows that the total worldwide energy consumption is projected to increase from 524 quadrillion (524×10^{15}) British thermal units (Btu) in 2010 to 820 quadrillion Btu in 2040. Most of this consumption is anticipated to come from non-OECD countries, and China and India are predicted to account for half of annual global energy consumption by 2040.⁴⁴

⁴¹ Stirling, A., 1998. On the economics and analysis of diversity. *Science Policy Research Unit (SPRU), Electronic Working Papers Series, Paper, 28*, pp.1-156.

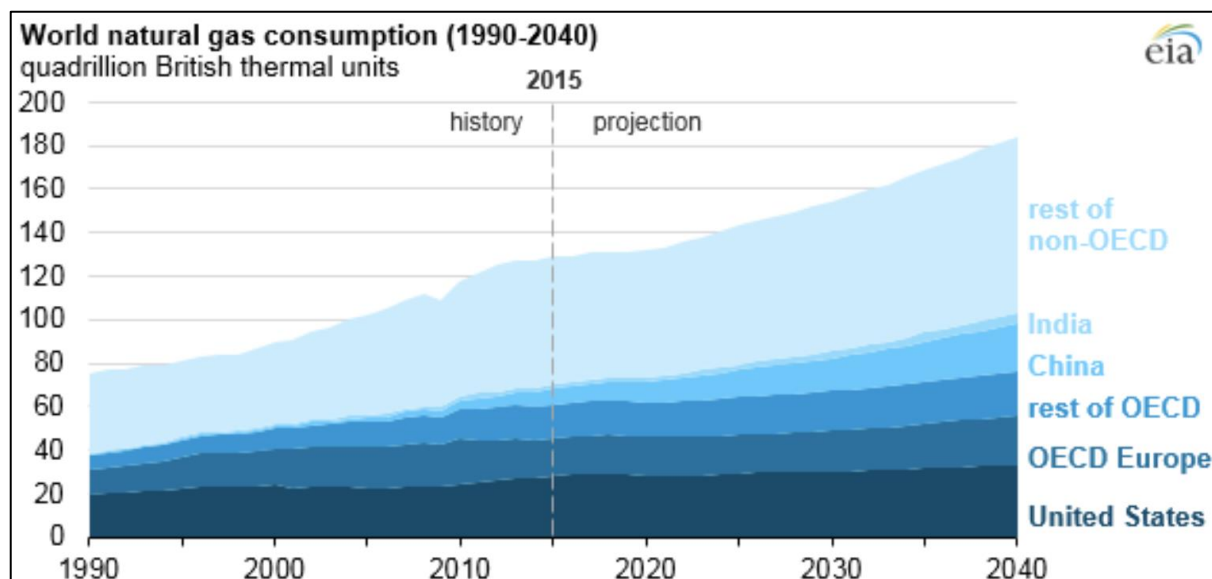
⁴² Ranjan, A. and Hughes, L., 2014. Energy security and the diversity of energy flows in an energy system. *Energy*, 73, pp.137-144.

⁴³ Chuang, M.C. and Ma, H.W., 2013. Energy security and improvements in the function of diversity indices—Taiwan energy supply structure case study. *Renewable and Sustainable Energy Reviews*, 24, pp.9-20.

⁴⁴ Energy Information Administration (US) and Government Publications Office eds., 2016. *International Energy Outlook 2016: With Projections to 2040*. Government Printing Office.

Furthermore, global energy demand is projected to substantially increase mostly because of developing countries in the Middle East, Africa, and Southeast Asia, over the period 2015-2040. In other words, the worldwide annual energy consumption rate will be at least doubled and perhaps tripled before the end of the century. It is commonly suggested by analysts that achieving 1% economic growth initiates an increase in energy demand of 1.5%. For example, the gross domestic product (GDP) of China has been increasing in recent years by 7-10% per year, resulting in the need for one new large power plant (producing 1000 MW) per week.⁴⁵

Figure 2- 1: Historical and projected global energy consumption by 2040.



Source: Energy Information Administration, International Energy Outlook 2017.

However, the International Energy Outlook 2017 (issued by Energy Information Administration, 2017 early release) appears to forecast lower global oil prices than in the 2015 report, at least in the short-term.⁴⁶ For many years, growing concerns about the future availability of oil resources have been raised amongst a number of energy scholars, analysts, consultants, and decision makers. In fact, there is continuous debate about how fast the world's oil production peak will be reached and when oil supplies will be exhausted.

During the past decade, the controversial discussion was thoroughly studied and examined in a series of papers published by oil and gas journals. However, the Hubbert Peak Theory denotes

⁴⁵ Lin, J., 2007. Energy conservation investments: A comparison between China and the US. *Energy policy*, 35(2), pp.916-924.

⁴⁶ Energy Information Administration (US) and Government Publications Office eds., 2017. *International Energy Outlook 2017: With Projections to 2040*. Government Printing Office.

that world oil supply had peaked already in the early 2000s, or would peak soon, when half of the world's reserves had been extracted. He proposed that any finite resource such as oil, gas, coal, or uranium follows a bell-shaped production curve, meaning that oil production under consistent economical and geological conditions increases to a peak then begins to decrease, and the decrease mirrors the rise in production.⁴⁷ His theories have gained much credibility after his successful prediction of the rise and fall in US oil production, which encouraged a number of scholars, analysts, and researchers to adapt his bell-shaped curve model to other countries around the world.

Ken Deffeyes supported Hubbert's theories and published three books (Hubbert's Peak in 2001, Beyond Oil in 2005, and When Oil Peaked in 2010) that explained his own rationale, concluding that global oil production would continue to follow a bell-shaped curve, with a smooth decline somewhere in the middle of 2005.⁴⁸

Thus, it has been proposed that 30 of 54 of the largest oil-producing countries in the world have passed their production peaks and are now in decline, including Oman.⁴⁹ A previous review of a wide range of data on oil discovery and production supports this (table 2-1).

Table 2- 1: The peak and depletion of conventional crude oil by country

Country	Date of peak discovery	Date of peak production	% Discovered	% Depleted	Ultimate Production (billion barrels)
China	1960s	2006	93	47	57
Canada	1950s	1973	95	76	25
Iran	1960s	1974	94	76	130
Iraq	1970's	2019	87	20	135
Indonesia	1950s	1977	93	65	31
Kuwait	1950s	1971	93	34	90
Libya	1960s	1970	93	42	55
Mexico	1950s	2002	94	55	55
Norway	1970s	2001	93	48	33
Oman	1960s	2001	94	49	5.5
Russia	1940s	1987	94	61	200
Saudi Arabia	1940s	2013	96	31	300
UAE	1960s	2014	94	23	78

⁴⁷ Hubbert, M.K., 1949. Energy from fossil fuels. *Science*, 109(2823), pp.103-109.

⁴⁸ Deffeyes, K.S., 2010. *When oil peaked*. Hill and Wang.

⁴⁹ Group, B., 2009. BP Statistical Review of World Energy, June 2009. Nuclear Energy www.bp.com/statisticalreview. doi:bp.com/statisticalreview

UK	1970s	1999	94	63	32
USA	1930s	1972	98	88	195
Venezuela	1950s	1970	96	48	95
The world	1962	2005-2010	94	49	2100

Source: Mamdouh G. Salameh, 2008⁵⁰

Oil discovery in the USA was near its highest point in the 1930s, and 40 years later, oil production peaked. Thus, a number of energy analysts, consultants, and scholars have argued that since most of the world's oil discoveries probably occurred in the 1960s, then world oil production probably peaked around 2010.⁵¹ Campbell also predicted in his book, *Oil Crisis*, that world oil production would begin to decline by 2010.⁵² Similar thoughts were suggested by various individuals who used available data and geological assessments to develop projections for when oil production might peak. A view of recent projections is shown in table 2-2.

Table 2- 2: Projections of the peaking of the global oil production (based on Hirsch R.L, Bezdek R., & Wendling R.)⁵³

Projected date	Source of projection	Background & reference
2006-2007	Bakhitari, A.M.S.	Iranian Oil Executive
2007-2009	Simmons, M.R.	Investment banker
After 2007	Skrebowski, C.	Petroleum journal Editor
Before 2009	Deffeyes, K.S.	Oil company geologist (ret.)
Before 2010	Goodstein, D.	Vice Provost, Cal Tech
Around 2010	Campbell, C.J.	Oil company geologist (ret.)
After 2010	World Energy Council	World Non-Government Org
2010-2020	Laherrere, J.	Oil company geologist (ret.)
2016	EIA nominal case	DOE analysis/ information

Source: Hirsch, R.L., Bezdek, R.M. and Wendling, R.M., 2005

All estimators developed complex global oil production capacity models that proposed that the oil peak would occur within the period 2004-2010. According to the Uppsala Hydrocarbon Depletion Study Group and the Association for the Study of Peak Oil and Gas, the US, Russian, and European oil production peaked many years ago, and the beginning of a world energy crisis could occur before 2020.⁵⁴

⁵⁰ Salameh, M., 2008. Peak Oil: a Reality or Hype?.

⁵¹ Banks, F.E., 2004. Beautiful and not so beautiful minds: an introductory essay on economic theory and the supply of oil. *OPEC review*, 28(1), pp.27-62.

⁵² Campbell, C.J., 2005. *Oil crisis*. Multi-science publishing.

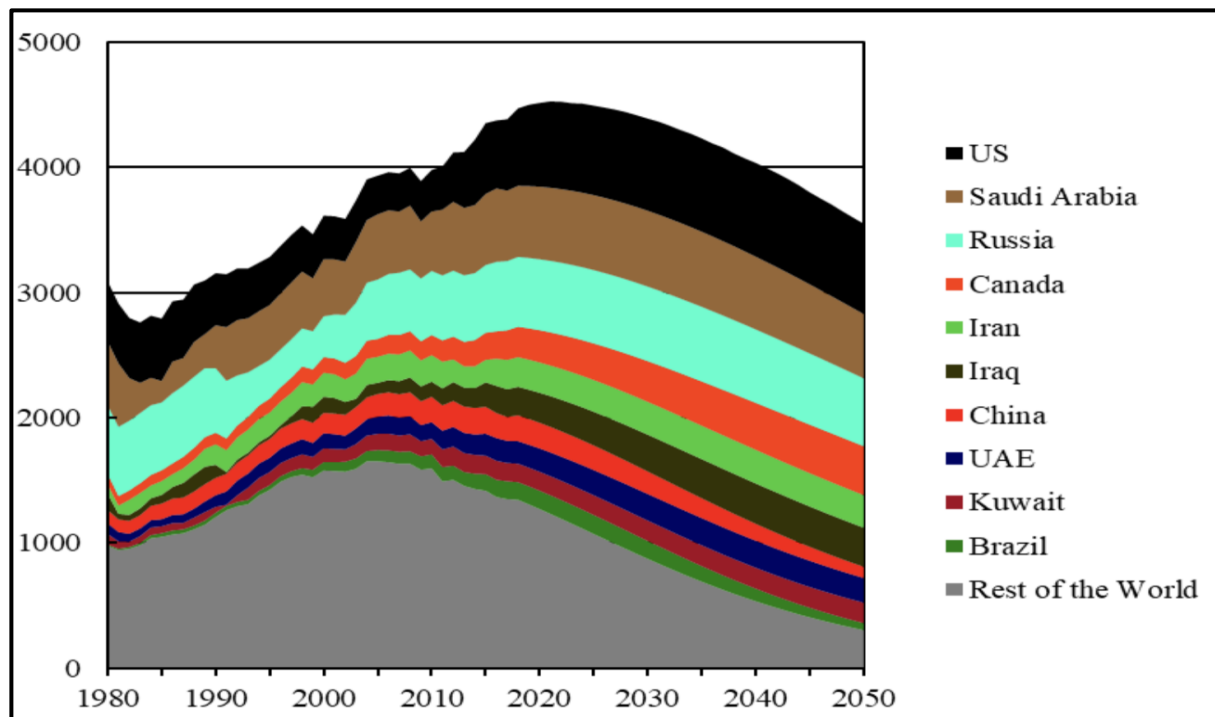
⁵³ Hirsch, R.L., Bezdek, R.M. and Wendling, R.M., 2005. *Peaking of world oil production: impacts, mitigation, & risk management* (No. DOE/NETL-IR-2005-093; NETL-TPR-2319). National Energy Technology Laboratory (NETL), Pittsburgh, PA, Morgantown, WV, and Albany, OR.

⁵⁴ all, V. (2018). *Uppsala Hydrocarbon Depletion Study Group | Peak Oil*. [online] Peak Oil. Available at: <https://www.peakoil.net/uhdsg/Default.htm> [Accessed 3 Sep. 2018].

According to the director of biochemistry at the University of York (York, UK) the exhaustion of fossil fuels is inevitable: “one day fossil fuels will run out and the world demand for them will not be met; the only imponderable is, when it will happen”.⁵⁵ In other words, there are different views about fossil fuel reserves and no one can predict exactly when extraction will lead to total depletion, but it will happen at some point.

Seifritz modified the fossil fuels reduction rate curve, which can get extremely different shapes, opposing the theory of Hubbert of the bell-shaped curve in predicting the end of the fossil fuels era.⁵⁶

Figure 2- 2: Oil and gas production peak around the world (Million Metric Tons, 1980-2050)⁵⁷



Source: BP Statistical Review of World Energy, 2018

<http://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html>.

Basically, a reduction in oil extraction capacity would lead to a shortage in supply and eventually increasing oil prices. Thus, passing the oil peak point could be well described as the ‘end of cheap oil’.⁵⁸ Given the fact that oil is a very important commodity traded globally, its price is crucially important to many economies around the world. In addition, once the peak

⁵⁵ Shafiee, S. and Topal, E., 2009. When will fossil fuel reserves be diminished?. *Energy policy*, 37(1), pp.181-189.

⁵⁶ Ibid

⁵⁷ Bp, 2018. BP Statistical Review of World Energy June 2018. <http://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html>.

⁵⁸ Campbell, C.J. and Laherrère, J.H., 1998. The end of cheap oil. *Scientific American*, 278(3), pp.78-83.

point is passed, an inevitable decline in availability will take place, and now it is more important to effectively allocate the remaining time to the transition to more sustainable resources.

Some people are more optimistic about worldwide oil production. For instance, the UK Energy Research Centre (UERC) has conducted a thorough study on the physical depletion of conventional oil and proposed that world oil production will not peak for several decades.⁵⁹ This view is also supported by studies by Jackson et al. (2004),⁶⁰ Davis (2003),⁶¹ and Wood et al. (2004)⁶² who claim that the world oil peak will most likely be closer to the middle of the 21st century than the beginning.

However, the accuracy level of the data that are available in the public domain regarding the quantity and quality of oil reserves is uncertain, and they seem to give more optimistic estimates than the data of other independent organisations that assess and report their methodology.⁶³ For example, surveys that are conducted by oil & gas journals and the Organization of the Petroleum Exporting Countries secretariat have never been subject to independent audit, because it could be understood as diplomatically insulting. These results are commonly believed to be inaccurate but are still included in the public data.⁶⁴ King et al. added that the reasons behind inaccurate data could be poor adherence to international standards in reporting oil reserve quantity, that resources might be categorised as economically exploitable reserves, and that misrepresenting could be done purposefully in view of a financial or political agenda.⁶⁵

⁵⁹ Sorrell, S., Speirs, J., Bentley, R., Brandt, A. and Miller, R., 2010. Global oil depletion: A review of the evidence. *Energy Policy*, 38(9), pp.5290-5295.

⁶⁰ Jackson, P. and Esser, R., 2004. Triple witching hour for oil arrives early in 2004—but, as yet, no real witches. *CERA Alert*. April, 7, p.98.

⁶¹ Davis, G., 2003. Meeting future energy needs: choices and possibilities. *Bridge*, 33(2).

⁶² Wood, J.H., 2004. Long-term world oil supply scenarios. *Energy Information Agency*, http://www.eia.doe.gov/pub/oil_gas/petroleum/feature_articles/2004/worldoilsupply/oilsupply04.html.

⁶³ Haider, G.M., 2000. World oil reserves: problems in definition and estimation. *OPEC review*, 24(4), pp.305-327.

⁶⁴ Laherrère, J., 2009. Oil peak or plateau. In *St. Andrews Economy Forum. ASPO France, France*.

⁶⁵ Owen, N.A., Inderwildi, O.R. and King, D.A., 2010. The status of conventional world oil reserves—Hype or cause for concern?. *Energy policy*, 38(8), pp.4743-4749.

Much evidence proposes that conventional oil production cannot fulfil growing demand, and that additional demand should be fulfilled by alternative sustainable energy resources.⁶⁶ However, many oil companies are investing heavily in exploration for new oil discoveries. They seem to ignore the fact that new discoveries would only extend the oil production peak for a few years, and only possibly slow the rate of production decline.⁶⁷

Although the topic of future oil production is heavily discussed and debated in the literature and among energy policymakers, what should be taken as fact is that at some time in the future, global oil production will reach the peak point (if not already), and eventually it will be totally consumed. This fact also applies for other fossil fuels such as coal and natural gas.

According to Bentley, about half of all the recoverable oil that has ever been discovered in the world—except that in the Middle East—has already been used.⁶⁸ Armstrong and Blundell argued that oil is being used about one million times faster than it was developed, given the fact that oil and gas took millions of years to form.⁶⁹ Even though there may be many other oil and gas reserves around the globe, these would never be enough to fulfil the rapidly increasing energy demand for long. According to the IEA, oil consumption has been increasing gradually from about a million barrels per day in 1900 to about 97 million barrels per day in late 2015.⁷⁰

The rapidly growing demand for oil, coupled with the continued depletion of oil reserves, could result in high energy prices, which could lead to political instability and disruption of the oil supplies that are crucial to spin the wheel of the world economy. This scenario of the future of energy is not a desirable one, and necessitates the reconsideration of energy policy towards sustainable means.⁷¹ Thus, the energy literature includes a large number of studies that have

⁶⁶ International Energy Agency, 2016. Energy and Air Pollution. World Energy Outlook - Special Report 266. doi:10.1021/ac00256a010

⁶⁷ Duncan, R.C., 2004. Hubbert revisited-2-Big jump in ultimate recovery not reverse, postpeak production decline. *Oil & gas journal*, 102(27), pp.18-21.

⁶⁸ Bentley, R.W., 2002. Global oil & gas depletion: an overview. *Energy policy*, 30(3), pp.189-205.

⁶⁹ Armstrong, F.A. and Blundell, K.M., 2007. *Energy... beyond oil*. OUP Oxford.

⁷⁰ Energy, I.R., 2016. Medium Term Market Report. *International Energy Agency: Paris, France*.

⁷¹ Leggett, J.K. and Leggett, J.K., 2005. *Half gone: oil, gas, hot air and the global energy crisis*. London: Portobello.

been conducted to inform of such possible catastrophic effects and propose policies to minimise negative effects of the unavoidable world oil production peak.⁷²

Deffeyes supported the idea of making these policies, and added that fossil fuels were a one-time gift that lifted the nations from subsistence agriculture to industrial economy.⁷³ The same view was expressed by Haiste in his book, *Oil Horror*, which stated clearly that “We have allowed oil to become vital to virtually everything we do. 90% of all our transportation, whether by land, air, or sea, is fuelled by oil. 95% of all goods in shops involve the use of oil. 95% of all our food products require oil use. Just to farm a single cow and deliver it to market requires six barrels of oil, enough to drive a car from New York to Los Angeles”.⁷⁴ In view of this, it would be impossible now to remove fossil fuels totally from the current energy system without dramatic changes to the world’s economy and people’s behaviour, without implementing policies and strategies that create a sustainable energy system of production and consumption; using specifically renewable energy resources on a large scale would assist in reducing the heavy reliance on oil.

2.2.2 Fossil fuels, environmental concerns, and renewable energy in relation to sustainability

Environmental issues, such as over-exploitation of natural and environmental resources, are just a few of many factors that have led to sustainable development becoming very popular, after the term first appeared in the formulation of the World Conservation Strategy in 1980.⁷⁵ In 1987, a very influential definition was recognised in the publication of ‘Our Common Future’, also known as the Brundtland Report, which defined sustainable development as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”.⁷⁶

⁷² Hirsch, R.L., Bezdek, R.M. and Wendling, R.M., 2005. *Peaking of world oil production: impacts, mitigation, & risk management* (No. DOE/NETL-IR-2005-093; NETL-TPR-2319). National Energy Technology Laboratory (NETL), Pittsburgh, PA, Morgantown, WV, and Albany, OR.

⁷³ Deffeyes, K.S., 2008. *Hubbert's peak: The impending world oil shortage (new edition)*. Princeton University Press.

⁷⁴ Haiste, O., 2008. *Oil Horror*. Lulu. com.

⁷⁵ Anand, S. and Sen, A., 2000. Human development and economic sustainability. *World development*, 28(12), pp.2029-2049.

⁷⁶ Brundtland report was published in 1987 after 900 days of extensive work put together by different groups of politicians, industrialists, civil servants, scientist, and experts on environment and

Scholars and policymakers strongly agree that sustainable development consists of three main pillars that need to be treated and balanced equally, including economic development, social equity, and environmental preservation.⁷⁷ Energy plays a crucial role in sustainable development and influences all three pillars.⁷⁸ Energy drives economic growth, because expansion in infrastructure and all related sectors of the economy such as industrial, tourism, transportation, and information and communication technology, require energy. From an environmental perspective, the use of non-renewable energy (ie, fossil fuels and nuclear energy) is accompanied by carbon emissions or waste issues, or both, which have a negative effect on the environment. Energy is essential for many basic human needs and services, and thus is important for society. Poor energy access and quality are often considered as issues of social injustice.⁷⁹

According to Munasinghe, energy objectives can be seen from the three pillars of sustainable development as:⁸⁰

1. Environmental: ensuring the sustainable use of energy and that materials obtained from the biosphere are not depleted, and the regeneration of resources (carrying capacity) has to be greater than or equal to their consumption.
2. Economic: allocating efficient resources that are affordable for consumers.
3. Social: aiming for equal distribution of resources between people in current and future generations.

development. The report was the key statement of sustainable development and aimed to discuss the environment and development as one concern.

⁷⁷ Drexhage, J. and Murphy, D., 2010. Sustainable development: from Brundtland to Rio 2012. Background paper prepared for consideration by the High Level Panel on Global Sustainability at its first meeting 19 September 2010.

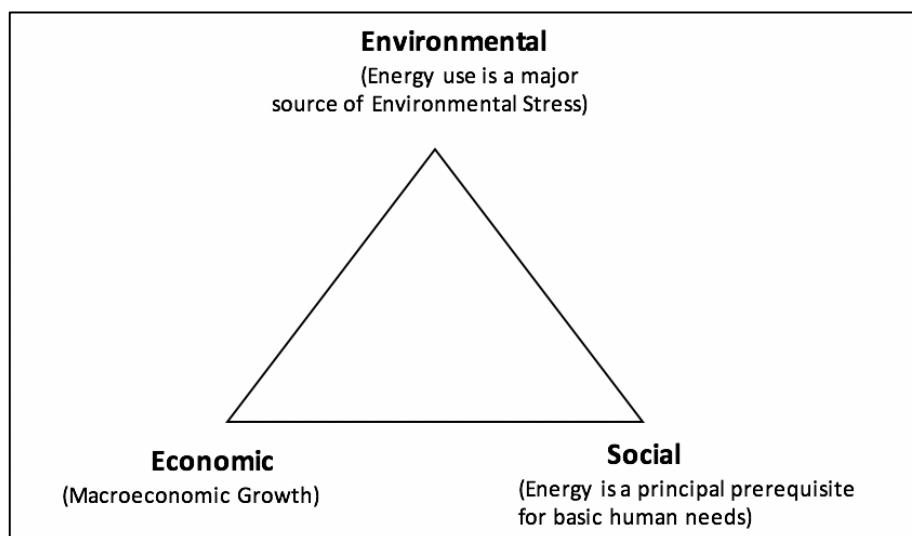
⁷⁸ Najam, A. and Cleveland, C.J., 2005. Energy and sustainable development at global environmental summits: an evolving agenda. In *The World Summit on Sustainable Development*(pp. 113-134). Springer, Dordrecht.

⁷⁹ Ibid

⁸⁰ Munasinghe, M., 2002. The sustainomics trans-disciplinary meta-framework for making development more sustainable: applications to energy issues. *International Journal of Sustainable Development*, 5(1-2), pp.125-182.

Figure 2-3 illustrates the linkage between energy and the three dimensions (social, economic, and environmental) of sustainable development as modified by Adil N. and Cutler J.

Figure 2- 3: Energy and sustainable development: deep linkage (2005).



Adil N. and Cutler J. redeveloped the work of Munasinghe to give the diagram in Figure 2-3 that highlights three important dimensions of sustainable development, and shows how energy plays a pivotal role in mapping onto each of these dimensions. In other words, people should use energy with a balance between economic growth and environmental protection—ie, without damaging the biosphere that supports life such as water, air, soils, and organisms. During the 1980s, the link between energy consumption and environmental damage became more obvious, because of environmental issues that arose, including pollution, resource depletion, and global warming.⁸¹ Since then, the scientific literature has increasingly recognised that energy extraction, transport, and use impact the environment directly and indirectly, and this is an important consequence of serving benefits to society, including providing the basic human needs of water, food, and shelter, and providing other luxuries to enhance the quality of life.⁸²

The use of fossil fuels such as petroleum, coal, and natural gas are accompanied by the production of CO₂, sulphur, methane, nitrogen oxide, and heavy metals.⁸³ According to the

⁸¹ Rosen, M.A. and Dincer, I., 2001. Exergy as the confluence of energy, environment and sustainable development. *Exergy, an International journal*, 1(1), pp.3-13.

⁸² Griggs, D.J. and Noguera, M., 2002. Climate change 2001: the scientific basis. Contribution of working group I to the third assessment report of the intergovernmental panel on climate change. *Weather*, 57(8), pp.267-269.

⁸³ Energy Information Administration (US), 2012. *Annual energy review 2011*. Government Printing Office.

United Nations Framework Convention on Climate Change,⁸⁴ these anthropogenic emissions to the environment cause a wide range of global and regional environmental issues such as climate change, urban smog, acid rain, and contamination of soil and water.⁸⁵

In addition, activity in the energy sector has had an enormous impact on the local environment. For example, strip mining of coal (mostly lignite) interrupts with the natural habitat. According to Matthews, the impact of waste on the local environment was calculated to be that 6 tons of waste is generated by each ton of coal mined.⁸⁶ Oil and gas exploration and extraction processes also have significant effects, because toxic waste is released from drilling operations. Naturally, this environmental effect of oil drilling applies to Oman and the rest of the world. There is a direct link between energy resource extraction and environment deterioration, which cannot be avoided unless effective and efficient use of specific approaches and technologies are adopted. Thus, achieving sustainable development requires not only a continuous supply of energy resources to society, but also specific techniques for its generation from the raw materials.⁸⁷

Part of the process of achieving sustainable development is to measure and assess the progress of energy sustainability through establishing indicators. Many conceptual approaches have been developed, among which two have been widely accepted. Pearce and Atkinson categorised sustainability into weak and strong sustainability.⁸⁸

The idea of weak sustainability is that natural capital (natural resources that generate goods and services) can be substituted by manmade goods and services (manufactured materials) without decreasing the total stock of natural capital for future generations.⁸⁹ In other words, finite natural resources such as fossil fuels (non-renewable resources) can be used and then

⁸⁴ Blodel, D., Meyer-Ohlendorf, N., Schlosser-Allera, C. and Steel, P., 2006. United Nations Framework Convention on Climate Change: Handbook. In *United Nations Framework Convention on Climate Change: handbook*. UNFCCC.

⁸⁵ Elliott, J.A., 2012. *An introduction to sustainable development*. Routledge.

⁸⁶ Matthews, E., Amann, C., Bringezu, S., Hüttler, W., Ottke, C., Rodenburg, E., Rogich, D., Schandl, H., Van, E., Voet, D. and Weisz, H., 2000. The weight of nations-material outflows from industrial economies. In *World Resources Institute*.

⁸⁷ Rosen, M.A. and Dincer, I., 2001. Exergy as the confluence of energy, environment and sustainable development. *Exergy, an International journal*, 1(1), pp.3-13.

⁸⁸ Gutés, M.C., 1996. The concept of weak sustainability. *Ecological economics*, 17(3), pp.147-156.

⁸⁹ Sustainablemeasures.com. (2018). Sustainability continued. [online] Available at: <http://sustainablemeasures.com/Training/Indicators/WeakStrg.html> [Accessed 4 Sep. 2018].

replaced, partially, with manmade technologies such as renewable resources (solar, tidal, wind, and other forms of renewable energy). Weak sustainability, as a result, can be used as long as the natural capital is substitutable. However, some scientists argue that it is difficult to value some natural capital, especially those resources that are close to extinction or cannot be replaced such as oil and gas. Therefore, it might not be possible to replace the loss of these natural resources with renewable energy sources.⁹⁰

By contrast, strong sustainability is the foundation of human survival and development, and its natural capital cannot be replaced or duplicated by manmade capital. The natural capital has its own unique characteristics and performs in such a way that people cannot mimic. For example, the depletion of the ozone layer cannot be fixed or substituted. Another important demarcating factor between strong sustainability and weak sustainability is the focus on human demands on resources and how they could be adapted to the existing resources.

Although weak sustainability focuses on potential abilities to refill the current resources with other alternatives, the strong sustainability argument stresses the need to control human use rather than find solutions to refill the outgoing resources. Hence, on the scale of sustainability types, there will be weak sustainability with resource expansion on one side, and strong sustainability controlling human demands for resources on the other side. From this view of an equilibrium comes the third approach to preserving sustainability, which is called moderate sustainability. Considering the sustainability types scale described, the moderate approach focuses equally on both sides. It argues that to maintain comprehensive sustainability, there is the need to both expand the existing resources and control human demands on them to reasonable levels.⁹¹ For the purpose of this research, moderate sustainability is taken as the ideal option, because it is more comprehensive to include both expansion of resources and reduction of demand, creating greater balance.

⁹⁰ Beckerman, W., 1994. 'Sustainable development': is it a useful concept?. *Environmental values*, 3(3), pp.191-209.

⁹¹ Williams, C.C. and Millington, A.C., 2004. The diverse and contested meanings of sustainable development. *Geographical Journal*, 170(2), pp.99-104.

Generally speaking, breakthrough technologies or innovation sustainability, within the context of energy, strive to achieve efficient energy use—eg, through energy conservation—as well as harness energy resources that have long-term sustainability.⁹²

- Renewable energy resources are constantly replenished without getting depleted by continuous use.
- The use of renewable energy resources doesn't create pollutants, especially solar and wind resources that produce almost no carbon emissions.
- The use of renewable energy resources doesn't have negative effects on human health.

It seems that only a few energy resources, specifically the renewable resources, can meet these criteria. Geller stated that “A sustainable energy future is possible through much greater energy efficiency and much greater reliance on renewable energy sources compared to current energy patterns and trends”.⁹³ However, balancing between the three pillars of sustainable development (environmental, social, and economic) quite often requires deep understanding of energy choices and the benefits and disadvantages that are associated with any particular option. For example, hydroelectric reservoirs have significant impact on the environment and society; residents have been removed from their houses and their living areas replaced by lakes in some countries such as India and China.⁹⁴ In addition, waste that settles in these reservoirs can generate significant toxic materials.⁹⁵

Renewable energy should also be environmentally sustainable. This happens when emissions that are released do not interact with the environment, or when the environment can remove waste emissions (chemical, thermal, and mechanical) so that no damage is caused.⁹⁶ However, all energy resources contribute some negative environmental impact. Thus, one of the challenges that sustainable development faces is environmental emissions that are generated to

⁹² Everett, R., Boyle, G., Peake, S. and Ramage, J., 2012. *Energy systems and sustainability: Power for a sustainable future*. Oxford University Press.

⁹³ Geller, H., 2012. *Energy revolution: policies for a sustainable future*. Island Press.

⁹⁴ McCully, P., 2001. *Silenced rivers: The politics and ecology of large dams*. London: Zed.

⁹⁵ Najam, A. and Cleveland, C.J., 2005. Energy and sustainable development at global environmental summits: an evolving agenda. In *The World Summit on Sustainable Development* (pp. 113-134). Springer, Dordrecht.

⁹⁶ Rosen, M.A. and Dincer, I., 2001. Exergy as the confluence of energy, environment and sustainable development. *Exergy, an International journal*, 1(1), pp.3-13.

some extent from all energy resources, which partially can be overcome through enhanced energy efficiency.⁹⁷

All energy resources have some advantages and disadvantages in certain circumstances, so there is probably no single right answer for every country when it comes to selecting from the options. It can thus be argued that renewable energy not only could reduce global pollutants, but also is a method towards a more sustainable energy system for the present and future. However, renewable energy resources are usually chosen to deal with current energy requirements and environmental issues. In addition, renewable energy resources can provide a number of important socioeconomic benefits such as diversification of energy supply, enhanced infrastructure development, equal accessibility to energy resources, and the creation of energy industry and employment opportunities.⁹⁸ It is beyond the scope of this research to assess the most sustainable form of energy production, but wind and solar energy are commonly considered sustainable resources.

2.3 Energy security

Oil security has been at the heart of energy policy agendas around the world, because of national economies' dependence on oil, and to a lesser extent, gas. National security issues first emerged in the global shock of 1973.⁹⁹ More than 50% of global oil resources are located in the Middle East,¹⁰⁰ and oil fulfils about 40% of global energy demand.¹⁰¹ Apart from energy security concerns, the Middle East has had many security problems such as various wars and conflicts between Arabs, Israelis, and Iranians,¹⁰² and the Arab Spring; it is not a stable region in general, and this in turn can affect energy prices.

⁹⁷ Elliott, J.A., 2012. *An introduction to sustainable development*. Routledge.

⁹⁸ Del Río, P. and Burguillo, M., 2008. Assessing the impact of renewable energy deployment on local sustainability: Towards a theoretical framework. *Renewable and sustainable energy reviews*, 12(5), pp.1325-1344.

⁹⁹ Cohen, G., Joutz, F. and Loungani, P., 2011. Measuring energy security: Trends in the diversification of oil and natural gas supplies. *Energy policy*, 39(9), pp.4860-4869.

¹⁰⁰ Bp, 2012. BP Statistical Review of World Energy June 2012. Nuclear Energy www.bp.com/statisticalreview.

¹⁰¹ Gupta, E., 2008. Oil vulnerability index of oil-importing countries. *Energy policy*, 36(3), pp.1195-1211.

¹⁰² Şen, Ş. and Babalı, T., 2007. Security concerns in the Middle East for oil supply: Problems and solutions. *Energy Policy*, 35(3), pp.1517-1524.

Oil remains one of the most consumed energy resources and there is a growing dependency on it; for example, industrial countries such as China and Japan highly depend on imported oil; they import about 18.6% and 7.3% of the total world crude oil imports, respectively.¹⁰³ Reliance on imported oil means putting a national economy at great risk, because the frequent fluctuation of oil prices and oil supply can be affected by geopolitical and economic instabilities, embargoes, trade disputes, and other disruptions.¹⁰⁴ However, natural gas is becoming an important source of energy also, and the consumption is steadily increasing. According to the IEA, the international spot trade of gas has increased ten-fold over the past decade.¹⁰⁵

With regards to energy security, it has been viewed as one of the key objectives of energy policy that align with economic performance and environmental protection.¹⁰⁶ However, the definition and dimensions of energy security seem to be changing and evolving as circumstances change over time. There is no broadly accepted definition of energy security.¹⁰⁷ In fact, some scholars have explored the term under four categories, including economic, policy, technological, and geopolitical aspects.¹⁰⁸

The vague definition of energy security across nations and among professionals has led to some agreements to standardise energy security measures. Sovacool, Mukherjee, Drupady, and Agostino describe over 20 metric measures of energy security, termed indexes, spanning almost 20 countries.¹⁰⁹ Therefore, it is possible to standardise many aspects of measuring energy security, and to provide a better way of exploring the extent to which a country's energy sources are sustainable or not. In fact, the ability to assess the level of sustainability of a country's energy resources is the main driver for the move toward diversification. This can

¹⁰³ Bp, 2018. BP Statistical Review of World Energy June 2018. www.bp.com/statisticalreview.

¹⁰⁴ Bielecki, J., 2002. Energy security: is the wolf at the door?. *The quarterly review of economics and finance*, 42(2), pp.235-250.

¹⁰⁵ US Energy Information Administration ed., 2011. *Annual Energy Outlook 2011: With Projections to 2035*. Government Printing Office.

¹⁰⁶ Kiriyaama, E. and Kajikawa, Y., 2014. A multilayered analysis of energy security research and the energy supply process. *Applied Energy*, 123, pp.415-423.

¹⁰⁷ Ang, B.W., Choong, W.L. and Ng, T.S., 2015. Energy security: Definitions, dimensions and indexes. *Renewable and Sustainable Energy Reviews*, 42, pp.1077-1093.

¹⁰⁸ Kiriyaama, E. and Kajikawa, Y., 2014. A multilayered analysis of energy security research and the energy supply process. *Applied Energy*, 123, pp.415-423.

¹⁰⁹ Sovacool, B.K., Mukherjee, I., Drupady, I.M. and D'Agostino, A.L., 2011. Evaluating energy security performance from 1990 to 2010 for eighteen countries. *Energy*, 36(10), pp.5846-5853.

happen by advising the policymakers on what to avoid and what to incorporate in energy exploration and exploitation methods, and to use energy locally as well as for export.

However, the move to renewable energy has been met with resistance in some oil-exporting countries that have not found a concrete reason to accept the move from the apparently abundant non-renewable resources to apparently available but hard to retrieve renewable resources, like wind and solar power. In addition, early adopters of diversification policies, especially the non-oil-producing countries, have embraced the idea and made efforts to boost their local energy production. For example, in 2014, Denmark generated 39% of its overall electricity from wind energy sources, and Germany generated 30% of its overall electricity from renewable sources.¹¹⁰

Energy diversification appeals to a considerable number of countries worldwide, particularly those that have carried out energy security assessments and found worrying results; thus, these countries are willing to change their energy plans for more diversified strategies. There is great variation in the level of energy security among countries, which has led to different conceptualisation of the need to diversify energy resources, both for domestic use and for export markets.¹¹¹

The economic benefits and losses to a country due to acceptance and adoption of alternative energy resources are different from one country to another, leading to different reactions of different authorities and politically influential factors that can encourage or discourage the call for energy diversification. The need for a change in policy towards energy diversification to improve energy security has been identified. However, this is not simple, and there are differences in the speed of renewable energy resource development in oil-producing countries. These observations further emphasise the negative effects of these non-renewable energy sources on the economy in the long term and the benefits of deploying the renewable alternatives that support sustainability and also improve national energy policy.

¹¹⁰ Sovacool, B.K., Mukherjee, I., Drupady, I.M. and D'Agostino, A.L., 2011. Evaluating energy security performance from 1990 to 2010 for eighteen countries. *Energy*, 36(10), pp.5846-5853.

¹¹¹ Cerović, L., Maradin, D. and Čegar, S., 2014. From the restructuring of the power sector to diversification of renewable energy sources: preconditions for efficient and sustainable electricity market. *International Journal of Energy Economics and Policy*, 4(4), pp.599-609.

2.3.1 Security of energy supply and demand

It is widely accepted that the equation between energy demand and energy supply needs to be balanced in order to shorten the gap in energy production and consumption. That being said, energy demand requires security of energy supply and energy supply requires security of demand, which is obvious in the economic perspective. For example, on the one hand, if any energy importing country requires energy as a feed-in for production and consumption purposes desires affordable and sustainable energy supply, therefore it wants security of supply. On the other hand, energy exporting country such as oil and gas, wants to have an a stable energy export flow at an appropriate price that can guarantee new energy investment projects and general socioeconomic development, therefore it requires a security of energy demand. Countries that export oil and gas like the GCC, including Oman, have economies that depend heavily on exporting these fossil fuels for producing most of their revenues. A lack of equilibrium or disruption in oil and gas prices leads to instability. Surplus supply causes sharp decline in prices and increases costs and the related storage risks. For example, a severe decrease in the international oil prices occurred between 2014 and 2016, due to excess supply from the Organization Petroleum Exporting Countries (OPEC), Russia, and the United States.¹¹² On the other hand, surplus demand leads to increase energy prices, which makes it a challenge for energy suppliers to increase energy extraction and production especially on a short notice. Therefore, a fluctuation in energy prices have direct impact on both producers and consumers, whereas stability and projected trends of energy prices is a win-win situation for both energy importers and energy suppliers. However, benefiting from energy prices predictability and stability for both importing and exporting countries does not mean that there is not competing interests. As a matter of fact, the security of energy supply relies on diversification of types of energy resources, diversification of suppliers, and an access from multiple energy distribution networks. On the contrary, the security of energy demand relies on the absence of alternatives of a specific source of energy, the absence of competitors who provide energy to particular market, and energy disruption such as trade disputes, embargoes, and political instabilities.

¹¹² Greening, L.A., Greene, D.L. and Difiglio, C., 2000. Energy efficiency and consumption—the rebound effect—a survey. *Energy policy*, 28(6-7), pp.389-401.

2.4 Energy efficiency and conservation

The terms energy efficiency and energy conservation are frequently, and incorrectly, used interchangeably. However, energy conservation specifically refers to reducing the use of energy, quite often with a behavioural change. For example, turning off lights on a regular basis or not cooling rooms with air conditioning when it is unnecessary. By contrast, energy efficiency refers to the efficient use of energy, and often it requires a technological improvement.¹¹³ In other words, applying energy efficiency makes consumption patterns more sustainable, including end-use energy efficiency. Also, it requires achieving the maximum energy output in industry, transportation, services, agricultural, and household appliances, using the minimum energy input.¹¹⁴ With regards to supply, energy efficiency requires optimisation of energy extraction, conversion, transportation, and distribution.¹¹⁵

Global energy efficiency of converting primary energy to useful energy is about 33%, which means two-thirds of primary energy is lost in the conversion process, either as heat or during transport.¹¹⁶ Improvement of end-use equipment can provide energy more economically than expansion of generation or distribution. As the world energy demand increases, creating an increasing gap between energy supply and demand, adaption to enhanced energy efficiency is one potential option. With increased energy efficiency, the lifespan of energy resources such as oil and gas will be increased, which will allow more time to develop alternatives before oil and gas run out to replace non-renewable energy resources.¹¹⁷ Energy efficiency measures can decrease the increase of national energy demand, therefore reducing the impact of energy supply constraints, and it can decrease the need for energy imports, promoting energy sustainability.¹¹⁸ Energy efficiency also delivers other benefits such as employment

¹¹³ Sovacool, B.K., Mukherjee, I., Drupady, I.M. and D'Agostino, A.L., 2011. Evaluating energy security performance from 1990 to 2010 for eighteen countries. *Energy*, 36(10), pp.5846-5853.

¹¹⁴ Vera, I. and Langlois, L., 2007. Energy indicators for sustainable development. *Energy*, 32(6), pp.875-882.

¹¹⁵ Spalding-Fecher, R., Winkler, H. and Mwakasonda, S., 2005. Energy and the World Summit on Sustainable Development: what next?. *Energy Policy*, 33(1), pp.99-112.

¹¹⁶ Sustainable Development: what next?. *Energy Policy*, 33(1), pp.99-112.

¹¹⁷ Anderson, D., 2004. *World Energy Assessment: Overview: 2004 Update*. United Nations Publications.

¹¹⁸ Greening, L.A., Greene, D.L. and Difiglio, C., 2000. Energy efficiency and consumption—the rebound effect—a survey. *Energy policy*, 28(6-7), pp.389-401.

opportunities, domestic economic development, and lowers the level of pollutants.¹¹⁹ Besides, small efforts in energy efficiency would add value to the nation through the significant financial cost savings.

Furthermore, energy conservation includes the reduction or elimination of unnecessary energy use. Many publications have been produced on the subject of energy conservation, which not only includes the reduction of energy use, but also highlights that a lot of energy-saving measures are also cost saving.¹²⁰

Conservation without doubt decreases energy demand, but it is not necessarily the ideal solution because it can also affect safety or comfort—eg, to reduce usage, one might not use air conditioning as often. By contrast, efficiency keeps the same level of output—eg, light or temperature level—but uses less energy to achieve it. Thus, applying a mixture of energy conservation and efficiency measures provides the best solution.¹²¹ However, in developing countries such as Oman, the number of new buildings and houses being constructed is increasing significantly and energy subsidies and tariffs do not encourage the use of efficient technologies.¹²² Developed countries are using building energy regulations to minimise energy consumption, including that used by heating or air conditioning.¹²³ Energy regulation is one of the most commonly accepted instruments that can play a pivotal role in improving energy conservation and efficiency in buildings,¹²⁴ and includes setting standards for the design and construction of buildings. The primary objectives of these codes and standards are to ensure that the people around and within the buildings are safe and healthy whilst setting a standard for energy-efficient design and construction.¹²⁵ The difference between energy codes and

¹¹⁹ Tonn, B. and Peretz, J.H., 2007. State-level benefits of energy efficiency. *Energy Policy*, 35(7), pp.3665-3674.

¹²⁰ Powell, J., Monahan, J. and Foulds, C., 2015. *Building futures: Managing energy in the built environment*. Routledge.

¹²¹ Greening, L.A., Greene, D.L. and Difiglio, C., 2000. Energy efficiency and consumption—the rebound effect—a survey. *Energy policy*, 28(6-7), pp.389-401.

¹²² Hui, S.C., 2000, August. Building energy efficiency standards in Hong Kong and mainland China. In *Proc. of the 2000 ACEEE Summer Study on Energy Efficiency in Buildings* (pp. 20-25).

¹²³ Birner, S. and Martinot, E., 2002. The GEF energy-efficient product portfolio: emerging experience and lessons. *Global Environment Facility Monitoring and Evaluation Working Paper*, 9.

¹²⁴ Environmentally sustainable buildings: Challenges and policies, 2003. , Environmentally Sustainable Buildings: Challenges and Policies. Organisation for Economic Cooperation and Development (OECD). doi:10.1787/9789264033863-en

¹²⁵ Iwano, J. and Mwashia, A., 2010. A review of building energy regulation and policy for energy conservation in developing countries. *Energy Policy*, 38(12), pp.7744-7755.

energy standards according to Bartlett et al, is that energy codes “specify how buildings must be constructed or performed, and are written in mandatory, enforceable language. States or local governments adopt and enforce energy codes for their jurisdictions”.¹²⁶ Energy standards “describe how buildings should be constructed to save energy cost-effectively”. The biggest proportion of energy consumption by buildings is for the cooling or heating, thus it is of great importance to enhance the energy efficiency of these processes. Many design factors can affect energy efficiency, starting from the basic elements of the orientation and shape of the building structure, which affect the heat gained from daylight, to complex elements such as the method of sealing joints between building materials and insulation. Reducing energy consumption of buildings can also be achieved through improving the design of the exterior, including walls, windows, roofs, and doors, as well as installing energy-efficient appliances.¹²⁷ However, it is worth mentioning that the effectiveness of building energy codes and standards differ considerably from country to country, mostly because of insufficient implementation and enforcement, especially in developing countries.¹²⁸ Some countries, such as Oman, do not have building codes for energy use, energy conservation, or carbon emission; whereas these are implemented in other countries such as the UK.

2.5 Energy pricing

Energy prices in some parts of the world—especially in the Middle East—maintain strict control of local energy prices by introducing subsidies, in order to meet the political and economic requirements for many years. The aims behind these low energy prices include meeting the welfare requirements by spreading energy access and helping low-income families, economic development such as encouraging industrial-sector growth and facilitating local consumption, and political consideration such as equal distribution of oil and gas returns in oil-rich countries.¹²⁹

¹²⁶ Bartlett, R., Halverson, M.A. and Shankle, D.L., 2003. Understanding building energy codes and standards. *Pacific Northwest National Laboratory*.

¹²⁷ Environmentally sustainable buildings: Challenges and policies, 2003. , Environmentally Sustainable Buildings: Challenges and Policies. Organisation for Economic Cooperation and Development (OECD). doi:10.1787/9789264033863-en

¹²⁸ UNEP-SBCI, 2007. Assessment of policy instruments for reducing greenhouse gas emissions from buildings. Environment 91.

¹²⁹ Fattouh, B. and El-Katiri, L., 2012. Energy subsidies in the Arab world.

The concept of subsidy has many different definitions in the literature, but generally it can be defined as “any government assistance, in cash or in kind, to private sector producers or consumers for which the government receives no equivalent compensation in return, but conditions the assistance on a particular performance by the recipient”.¹³⁰ In other words, governments provide help directly or indirectly through different actions, including cash subsidies, in-kind subsidies, and tax subsidies. The main advantages of energy subsidies can be categorised as follows:¹³¹

- They spread energy access; more people have access to electricity or modern forms of fuel for cooking, cooling, and transportation.
- They protect low-income families from high energy costs; governments tend to keep all energy services and prices below international prices, regardless of whether these subsidies are used by high-income or low-income families.
- They enhance the industrial sector; subsidised oil and gas can be given to energy-intensive industries (producers of cement, fertilizer, and petrochemicals), power stations, and manufacturers. Subsidising the industrial sector can encourage local firms to provide their services and products at affordable prices, improve export competitiveness, and reduce the rate of unemployment.
- They are important to political consideration or agenda; governments, especially in the Gulf Countries, tend to provide their citizens with abundant supplies of low-cost energy for many years, and this allows fairer distribution of wealth from natural resources.

Despite aiming to achieve some objectives of improving social welfare and encouraging industrialisation, energy subsidies have some negative effects in the Middle East, especially in the Gulf Cooperation Countries (GCCs), as follows:

- They increase energy intensity and reduce energy efficiency. Total primary energy consumption has declined in most parts of the world over the last 30 years except for in the GCCs, including Oman. Energy intensity growth rates have increased more than threefold and projections indicate an even greater increase in the energy intensity in future. Additionally, energy efficiency is low in GCCs, partly because of the old electricity generation plants, which require intensive energy and have great energy losses.
- They caused a significant increase in the consumption of oil and gas as well as electricity. Over the past three decades, oil and gas consumption have been increasing annually by 5% and electricity by 7%.

¹³⁰ Schwartz, M.G., Hugounenq, R. and Clements, M.B.J., 1995. *Government subsidies: concepts, international trends, and reform options*. International Monetary Fund.

¹³¹ Fattouh, B. and El-Katiri, L., 2012. Energy subsidies in the Arab world.

- The benefits are not distributed equally. Cheap energy provision is not equal in terms of the benefit received. High-income families tend to benefit more from subsidies for transportation fuels and electricity, because they have much higher energy consumption rates than low-income families.
- They cause a rapid increase in CO₂ emissions and local pollution. Reducing energy prices leads to higher energy use and discourages the conservation of energy, which consequently impacts negatively on the environment, for example by increasing greenhouse gas emissions.
- They discourage the development of alternative energies. Obstacles to the diversification of energy resources in the GCC include a number of different factors, such as the current abundance of oil and gas, which are more convenient in terms of price, storage, and reliability than renewables. Renewable resources face some financial and technical challenges such as dust effects, when dust on solar panels reduces performance significantly. The lack of diversity of energy resources is not only an environmental issue, but it is also a national energy security issue, specifically in terms of energy sustainability.

2.6 Renewable and non-renewable energy challenges and opportunities in oil-exporting countries

Although there are clearly different views, the impact of the continued production and consumption of oil and gas as the main source of energy continues to be negative in terms of energy security in the importing countries, and uncertainty of revenue in the oil-exporting countries, such as Oman and other GCCs. In fact, it is on the basis of assuring returns for oil- and gas-exporting countries that there is a call for the need to diversify energy resources. A diversified energy source would reduce the overdependence on oil and gas for domestic production and so more can be used for export, thus increasing revenues and allowing greater self-reliance.¹³² Many of the oil- and gas-producing countries have the best climates to harness and produce energy from solar and wind energy, because of large expanses of land that are sparsely populated. The view of oil-exporting countries needing to derive their income from oil and gas revenues could be eliminated by the use alternative energy resources.

Another benefit of diversified energy resources for energy-exporting countries is that it counters the problems caused by unstable oil and gas prices in the international markets. For example, prices drop when the production of oil increases significantly because new oil wells

¹³² Sovacool, B.K. and Brown, M.A., 2010. Competing dimensions of energy security: an international perspective. *Annual Review of Environment and Resources*, 35, pp.77-108.

that were sunk are discovered, and supply is greater than demand.¹³³ This leads to a general reduction of prices over time when the time value of money is factored in, as well as the vulnerability of oil and gas prices in the world markets. In fact, the various collaborations by oil-producing countries to control prices have proved unsuccessful, and the prices continue to fluctuate amid their efforts to stabilise them. This is due to uncontrollable factors such as varied consumption of oil and gas by the major importers, political factors, or energy incidents in the exporting countries. As a result, the oil-rich countries might not be sure what their actual worth in terms of oil in the international market is, thus making financial planning quite difficult. Ultimately, the local prices of oil and gas in the oil and gas-producing countries are too low, and residents are not motivated to use less domestically. This worsens the depleting returns that are introduced by the reduction in oil and gas demand worldwide. Alternative methods are crucial to warn against or avoid economic shocks of oil and gas price fluctuations in the global market.¹³⁴ Exporting countries have a wealth of information about their inevitable economic difficulty to know that they need to take action in the form of diversification immediately. Currently, the manner and level to which oil and gas-exporting countries like Oman are integrating energy diversification is unclear.

Opposite to the above scenario in oil-exporting countries like Oman and other GCCs, is that of countries that import these resources. The exporters would benefit from security of revenue from foreign exchange by allocating funds towards renewable energy projects. Oil and gas reserves will ultimately be depleted, whereas sustainable sources of energy like wind and solar power will offer longer-lasting solutions to energy security than non-renewable resources.

2.6.1 The potential of renewable energy technologies

Renewable (non-depletable) energy is generated from natural resources, including the sun, wind, biological sources (bioenergy), geothermal energy, water (hydro power), tides, and waves. Some examples of renewable energy technologies include wind turbines, solar

¹³³ Sethi, M., 2015. Location of greenhouse gases (GHG) emissions from thermal power plants in India along the urban-rural continuum. *Journal of Cleaner Production*, 103, pp.586-600.

¹³⁴ Greene, J.S. and Morrissey, M., 2013. Estimated pollution reduction from wind farms in Oklahoma and associated economic and human health benefits. *Journal of Renewable Energy*, 2013.

photovoltaics, solar thermal systems, and hydropower technologies.¹³⁵ A number of studies that have been conducted in Oman showed that, in Oman, solar and wind power have the highest potential of the renewable energies (Al Hatmi et al., 2013;¹³⁶ Kazem, 2011;¹³⁷ AER, 2009;¹³⁸ Al Badi et al., 2009¹³⁹).

Thus, as mentioned earlier, this thesis reviews solar and wind power because of their high potential in Oman. In fact, Oman is considered one of the best regions for solar energy and has the potential to meet all its domestic energy needs from solar energy, given the average number of days of clear sky during the year is about 342 throughout Oman.¹⁴⁰ According to Gastali and Charabi, almost all areas in Oman receive solar radiation between 5500 and 6000 Wh/m² per day most of the year, with the lowest levels of about 2500—which is still sufficient to power the country—seen in January.¹⁴¹ Figure 2-4 shows that the solar radiation in Oman exceeds 2200 kWh/m² per year.¹⁴²

¹³⁵ Nehrenheim, E., 2018. Introduction to Renewable Energy, in: Encyclopedia of the Anthropocene. Elsevier, pp. 405–406. doi:10.1016/B978-0-12-809665-9.09138-2

¹³⁶ Al Hatmi, Y. and Tan, C.S., 2013. Issues and challenges with renewable energy in Oman. *Gas (BCM)*, 4(9), pp.212-218.

¹³⁷ Kazem, H.A., 2011. Renewable energy in Oman: Status and future prospects. *Renewable and Sustainable Energy Reviews*, 15(8), pp.3465-3469.

¹³⁸ Authority for Electricity Regulation, Oman (2008). Study on Renewable Energy Resources, Oman Final Report. [online] muscat. Available at: http://regulationbodyofknowledge.org/wp-content/uploads/2013/09/AuthorityforElectricityRegulation_Oman_Study_on.pdf [Accessed 4 Sep. 2018].

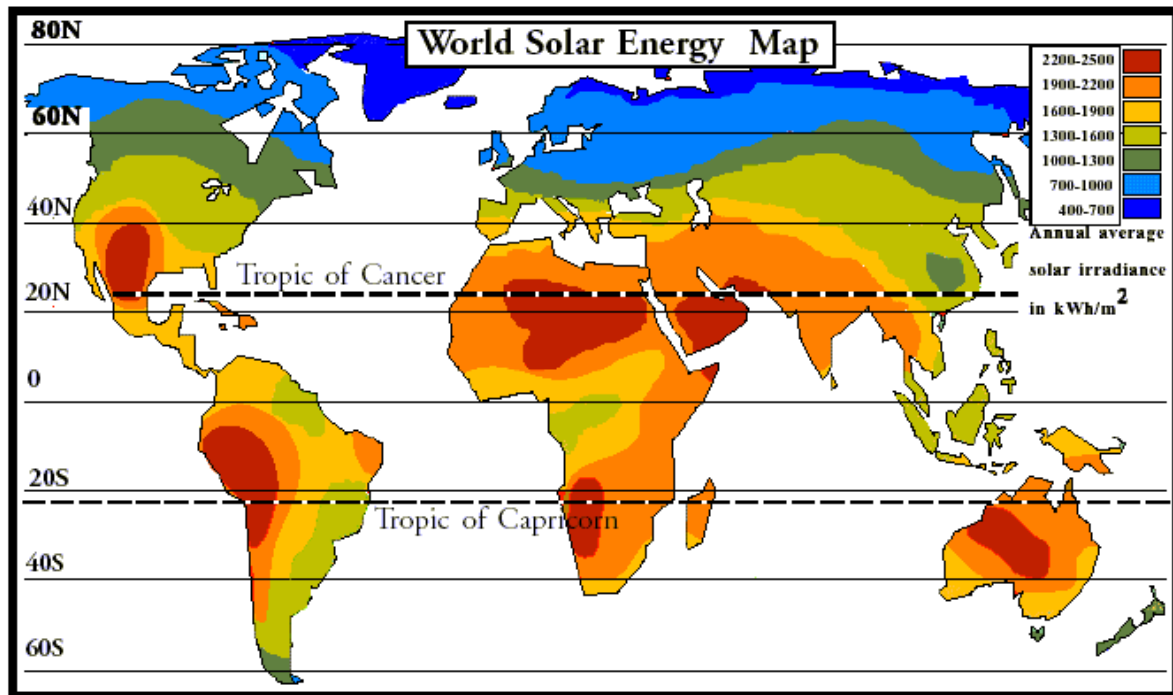
¹³⁹ Al-Badi, A.H., Malik, A. and Gastli, A., 2009. Assessment of renewable energy resources potential in Oman and identification of barrier to their significant utilization. *Renewable and Sustainable Energy Reviews*, 13(9), pp.2734-2739.

¹⁴⁰ Al Hatmi, Y. and Tan, C.S., 2013. Issues and challenges with renewable energy in Oman. *Gas (BCM)*, 4(9), pp.212-218.

¹⁴¹ Sultan, A.Y., Charabi, Y., Gastli, A. and Al-Alawi, S., 2010. Assessment of wind energy potential locations in Oman using data from existing weather stations. *Renewable and Sustainable Energy Reviews*, 14(5), pp.1428-1436.

¹⁴² International network for sustainable energy (2018). world solar energy map. [image] Available at: <http://www.inforse.org/europe/dieret/Solar/solar.html> [Accessed 4 Sep. 2018].

Figure 2- 4: World solar energy map (2018)



Source: International network for sustainable energy, world solar energy map (2018).

In addition to the potential of solar energy, a number of studies (Kazem, 2011;¹⁴³ Al-Badi A, 2012;¹⁴⁴ Al- Yahyahi, 2010;¹⁴⁵ AER, 2009;¹⁴⁶ Al Ismaili, 1997¹⁴⁷) have been conducted in Oman and concluded that several locations have a high potential for harnessing wind energy. These locations are in the southern and eastern regions of Oman near the sea, with an average wind speed of more than 4.5 m/s throughout the year.¹⁴⁸ For demonstration purposes, Figure 2-5 illustrates the average wind speed for four different cities in Oman:

¹⁴³ Kazem, H.A., 2011. Renewable energy in Oman: Status and future prospects. *Renewable and Sustainable Energy Reviews*, 15(8), pp.3465-3469.

¹⁴⁴ Al-Yahyai, S., Charabi, Y., Gastli, A. and Al-Badi, A., 2012. Wind farm land suitability indexing using multi-criteria analysis. *Renewable Energy*, 44, pp.80-87.

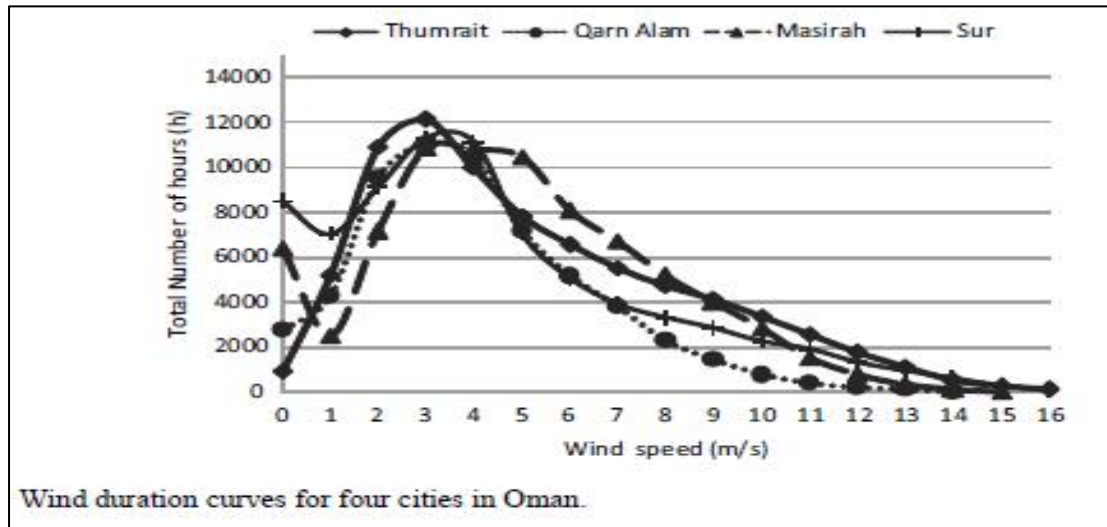
¹⁴⁵ Sultan, A.Y., Charabi, Y., Gastli, A. and Al-Alawi, S., 2010. Assessment of wind energy potential locations in Oman using data from existing weather stations. *Renewable and Sustainable Energy Reviews*, 14(5), pp.1428-1436.

¹⁴⁶ Authority for Electricity Regulation, Oman (2008). Study on Renewable Energy Resources, Oman Final Report. [online] muscat. Available at: http://regulationbodyofknowledge.org/wp-content/uploads/2013/09/AuthorityforElectricityRegulation_Oman_Study_on.pdf [Accessed 4 Sep. 2018].

¹⁴⁷ Al-Ismaili, H.A. and Probert, S.D., 1997. Energy overview for the sultanate of Oman. *Applied energy*, 57(4), pp.287-325.

¹⁴⁸ Al-Badi, A.H., 2011. Wind power potential in Oman. *International Journal of Sustainable Energy*, 30(2), pp.110-118.

Figure 2- 5: Annual wind speed for four cities in Oman (Albadi, 2011)



Source: Al-Badi, A.H., 2011

As mentioned, based on the studies that have been conducted in Oman, solar and wind energy are the desirable choices of renewable energy resources in Oman. The following sections intend to provide a general overview of these potential renewable energy technologies for Oman.

2.6.1.1 Wind

It is widely known that wind is a form of solar energy produced by the heating of the atmosphere by the sun, the Earth's rotations, and the irregularities of the surface of the Earth. The kinetic energy of the air flow or wind can be converted into mechanical energy, then electricity, using a wind turbine. To achieve the greatest benefit from the wind, the turbine should be positioned in a location with frequently high wind speeds.¹⁴⁹ The wind turbine itself usually contains a tower and a rotor, most often with three blades (shown in Figure 2-6). Commonly, wind turbines are put together in large arrangements called wind farms. Wind turbines can generate electricity between 1.5 and 5.0 MW in capacity, which are used to supply the power grid. Smaller wind turbines can generate between 0.1 and 20.0 kW and usually operate in remote areas.¹⁵⁰

¹⁴⁹ Manwell, J.F., McGowan, J.G. and Rogers, A.L., 2010. *Wind energy explained: theory, design and application*. John Wiley & Sons.

¹⁵⁰ Ibi

Figure 2- 6: A modern wind turbine (2009)



Source: Authority for Electricity Regulation, study on renewable energy resources (2009), Oman.

Wind power offers many advantages, including that it is a clean fuel source, reasonably cost-effective, and it helps to diversify the national energy portfolio. Furthermore, wind turbines only use a small area of the available land, so can be built on existing farms or grazing areas.¹⁵¹ However, a notable challenge is that wind power is an intermittent power supply, because of the intermittent nature of wind, which is partly unpredictable. This means that wind power may not be available when electricity demand occurs. Also, there is increasing concern from residents that wind turbines produce noise and optical distortions, such as flickering shadows in the landscape, on-shore. Wind turbines are about 40% more expensive off-shore, and they also can have a negative impact on marine life. High-speed on-shore wind sites are usually located in remote areas, and although this is good in terms of reducing domestic disturbances, they might require substantial infrastructure development such as building new transmission lines and integrating wind power into the grid.¹⁵² Another important factor that should be taken

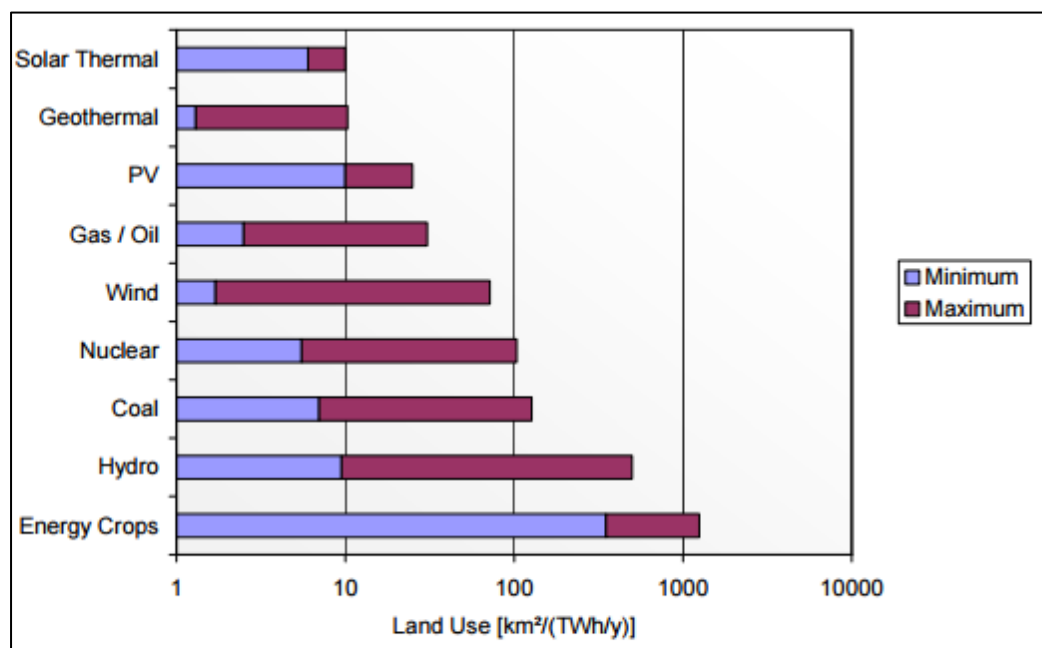
¹⁵¹ Vision, W., 2015. A new era for wind power in the United States. *US Department of Energy*.

¹⁵² Wagner, H.J., 2013. Introduction to wind energy systems. In *EPJ Web of Conferences* (Vol. 54, p. 01011). EDP Sciences.

into account when looking at the different technologies is the land requirement. Figure 2-7 compares maximum and minimum values for the area of land required for lifecycle use—ie, the total time from raw material extraction to disposal or recycling—of different power technologies per annual generated electricity (TWh/year).

However, it must be kept in mind that these values are gathered from different sources and using different methods, so the results are not necessarily comparable to each other. According to these data, it appears that solar technologies (including raw material exploitation, operation, infrastructure, and disposal) are the most area-efficient technology, in terms of their lifecycle use of land. Notably, the solar power data were favourable when compared with those of wind, oil and gas, or nuclear technologies.¹⁵³

Figure 2- 7: Maximum and minimum values for the life-cycle land requirements per unit of produced electricity for different electricity technologies



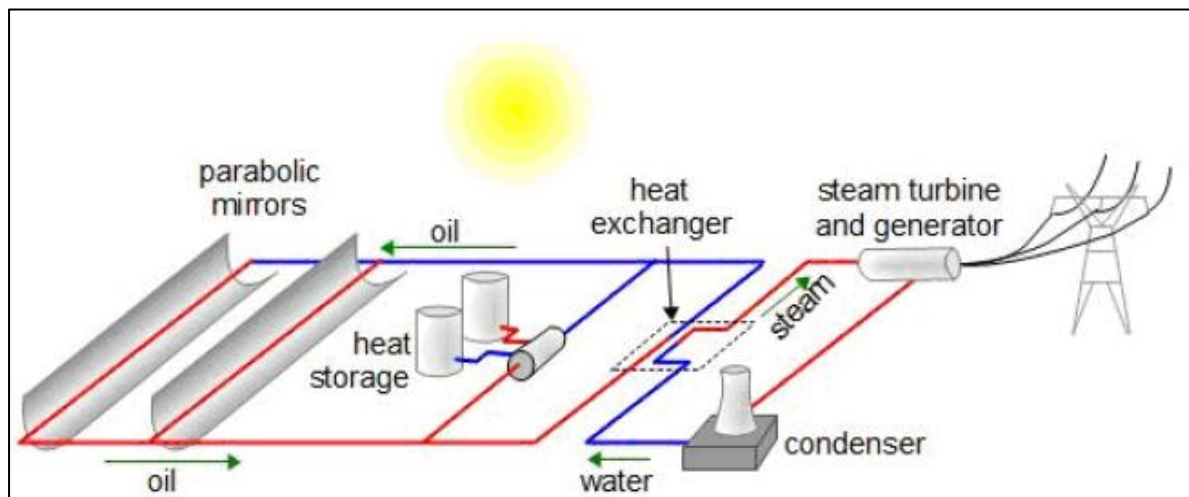
Source: German Aerospace Centre (DLR), 2005

¹⁵³ Center, G.A., 2005. Concentrating solar power for the Mediterranean region. *German Aerospace Center (DLR) Institute of Technical Thermodynamics, Section Systems Analysis and Technology Assessment, Stuttgart.*

2.6.1.2 Concentrating solar thermal technology

Concentrated solar power (CSP) systems generate electricity by harnessing and concentrating thermal solar energy using a variety of techniques. CSP is classified depending on whether the solar flux is concentrated by parabolic dish-shaped reflectors, parabolic trough-shaped mirror reflectors, or a solar power tower CSP.¹⁵⁴ It should be taken into account that CSP also refers to concentrating solar photovoltaic energy, yet for the purpose of this study CSP is only used to refer to technology used to concentrate solar thermal energy, more specifically to parabolic trough solar systems. This is because parabolic trough-shaped mirror reflectors are the most attractive technology for solar thermal power plants, because they are a cheap, relatively simple technology that is efficient.¹⁵⁵ The main component of the parabolic trough system is a long array of U-shaped mirrors curved to reflect sunlight into a tube, usually holding water, oil, and other fluids, as illustrated in Figure 2-8.

Figure 2- 8: A typical parabolic CSP technology



Source: Chu, 2011¹⁵⁶

When the concentrated sun's rays hit the tube, a working fluid gets heated to a high temperature, reaching up to 600°C. Next, the hot fluid passes through a heat exchanger that generates steam, which is piped through a steam turbine to generate electricity.¹⁵⁷

¹⁵⁴ Chu, Y. and Meisen, P., 2011. Review and comparison of different solar energy technologies. *Global Energy Network Institute (GENI)*, San Diego, CA.

¹⁵⁵ Quaschnig, V. and Muriel, M.B., 2002. Solar power-photovoltaics or solar thermal power plants?. *VGB POWERTECH-INTERNATIONAL EDITION*-, 82, pp.48-52.

¹⁵⁶ Chu, Y. and Meisen, P., 2011. Review and comparison of different solar energy technologies. *Global Energy Network Institute (GENI)*, San Diego, CA.

¹⁵⁷ Huber, J., 2004. *New technologies and environmental innovation*. Edward Elgar Publishing.

One of the main advantages of parabolic trough technology is that it contains heat storage space, which can be used to fill the gap between energy supply and demand when needed, and can provide electricity during the night when solar energy supply is low. In other words, parabolic trough technology might overcome the issue of solar intermittency. In addition, less time is required to build parabolic trough plants than photovoltaic power systems, because the main materials used are glass and steel, which are abundantly available, unlike the fabricated silicon used in photovoltaic systems, which requires intensive energy to make.¹⁵⁸ According to Chu, the most cost-effective large-scale renewable power comes from CSP systems, because few materials are required to make the reflective surfaces required.¹⁵⁹ Therefore, Oman, with some of the highest levels of solar radiation in the world, is positioned well for accommodating CSP technology. In fact, in the year 2012, a joint project between Petroleum Development Oman (PDO) and GlassPoint Solar was initiated using CSP to generate steam for the purpose of oil extraction, rather than the traditional method of burning gas to produce the steam. The results of the pilot project were positive, and showed that CSP can possibly be used as an alternative for producing steam. As stated by Rod MacGregor, president of GlassPoint Solar, “the oil and gas industry is the next major market for solar energy. It takes a tremendous amount of energy to produce heavy and viscous oil, with a typical oil field consuming the same amount of energy as a small city. PDO is the global leader in oil and gas innovation and the first to realize the value of using solar to replace traditional fuel sources to generate steam for EOR”.¹⁶⁰

2.6.1.3 Solar photovoltaic technology

Unlike CSP technology, which uses heat to produce electricity, solar photovoltaic technology converts radiant energy directly into electrical energy, without going through the process of heat conversion.¹⁶¹ In summary, when sunlight falls upon a semiconductor material, causing

¹⁵⁸ Kreith, F. and Goswami, D.Y., 2007. *Handbook of energy efficiency and renewable energy*. Crc Press.

¹⁵⁹ Chu, Y. and Meisen, P., 2011. Review and comparison of different solar energy technologies. *Global Energy Network Institute (GENI)*, San Diego, CA.

¹⁶⁰ Petroleum Development Oman (PDO). (2018). Miraah Solar. [online] Available at: <http://www.pdo.co.om/en/technical-expertise/solar-project-miraah/Pages/default.aspx> [Accessed 4 Sep. 2018].

¹⁶¹ Cassedy, E.S., 2000. *Prospects for sustainable energy: a critical assessment*. Cambridge University Press.

excitation of electrons, an electrical voltage is generated. The electricity produced can either be used directly or stored in a battery.¹⁶²

The first photovoltaic cells were developed in the USA in 1954, and the main purpose was to run a space satellite from their energy.¹⁶³ After this during the 70s, the oil-shock created much focus on the development and commercialisation of solar energy technologies. In the 80s, however, a sharp decline in oil prices occurred, which led the solar energy industry to suffer, because of poor policy support.¹⁶⁴ Since the year 2000, the solar energy sector has regained much interest from investors, with a significant average annual growth rate of 49%. In 2013, a total of around 37 GW of new photovoltaic capacity was created from about 30 different countries, raising the total global installed capacity of solar energy to more than 135 GW compared with the tiny capacity in the early 90s.¹⁶⁵

Solar photovoltaic technology has a number of advantages over other renewable energy systems, including that they are lightweight, have lower operation and maintenance requirements, have stable parts, and a long life-cycle durability.¹⁶⁶ Solar photovoltaic systems are the most popular renewable technology that is used to generate electricity. Solar energy is the largest source of renewable energy supply in the world, given that the effective solar radiation that shines on the surface of the Earth ranges from 0.06 kW/m² to 0.25 kW/m².¹⁶⁷ Figure 2-9 illustrates the world investment in renewable energy resources by different technologies.

technical potential of different renewable energy technologies using the current conversion efficiencies.

¹⁶² International Energy Agency (IEA): 2014, Technology roadmap solar photovoltaic energy.

¹⁶³ Iles, P.A., 2001. Evolution of space solar cells. *Solar Energy Materials and Solar Cells*, 68(1), pp.1-13.

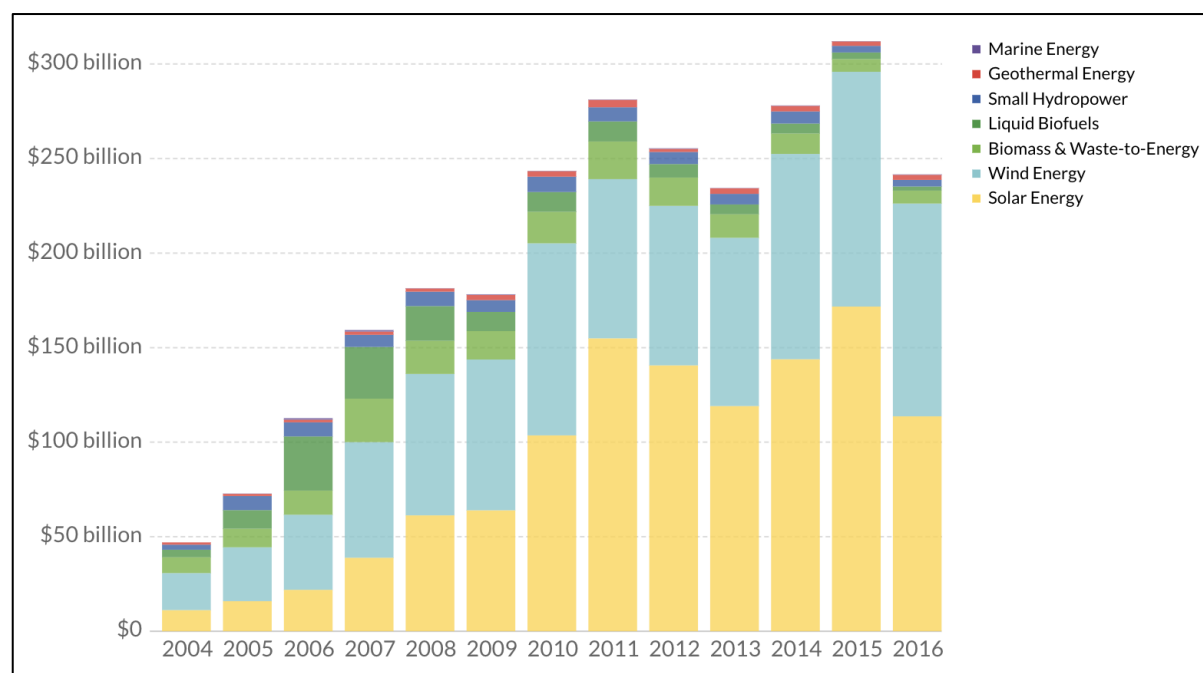
¹⁶⁴ Bradford, T., 2008. *Solar revolution: the economic transformation of the global energy industry*. MIT Press.

¹⁶⁵ International Energy Agency (IEA): 2014, Technology roadmap solar photovoltaic energy.

¹⁶⁶ Timilsina, G.R., Kurdgelashvili, L. and Narbel, P.A., 2011. *A review of solar energy: markets, economics and policies*. The World Bank.

¹⁶⁷ Chu, Y. and Meisen, P., 2011. Review and comparison of different solar energy technologies. *Global Energy Network Institute (GENI)*, San Diego, CA.

Figure 2- 9: World investment in renewable energy resources, by technology



Source: International Renewable Energy Agency (IRENA), 2017

The graph shows that the investment (measured in USD per year) in the world renewable energy technologies have been taking an increasing share, especially solar and wind energy resources. The trend shows that the investments in solar and wind energy are the dominant renewable technologies of the future. ¹⁶⁸

An assessment study of land requirement for harnessing solar power to generate electricity was done by Kurokawa et al. (2007), and they showed that using just 4% of the surface area of the world's desert for collecting solar energy would be sufficient to generate enough electricity to fulfil the present worldwide energy needs. ¹⁶⁹ Similarly, assessments suggest that the use of just 0.71% of the European land mass, covered with current photovoltaic panels, will fulfil the continent's entire electricity requirements. Furthermore, in many parts of the world 1 km² of land is sufficient to produce more than 125 gigawatt hours (GWh) of electricity per annum. For example, it is suggested that 1% of China's uninhabited land (26,300 km²) located in the northern and western regions, could generate about 1,300 GW of electricity, which is about

¹⁶⁸ International Renewable Energy Agency (IRENA)., 2019. Data and Statistics - IRENA Resource. [online] Available at: <http://resourceirena.irena.org/gateway/dashboard/index.html> [Accessed 29 Mar. 2019].

¹⁶⁹ De Vries, B.J., Van Vuuren, D.P. and Hoogwijk, M.M., 2007. Renewable energy sources: Their global potential for the first-half of the 21st century at a global level: An integrated approach. *Energy policy*, 35(4), pp.2590-2610.

double China's entire generation capacity that is anticipated for 2020 using current technology. Moreover, in the USA, installation of solar panels over an area of 23,418 km² in the southwestern region could match the current electricity generation capacity of 1,076 GW, and fill the gap between supply and demand.¹⁷⁰

2.6.1.4 Energy strategies and sustainability in the GCC countries

There is an increasing debate in the literature on the energy sustainability of the Gulf Cooperation Council countries (GCC), namely Oman, Bahrain, Saudi Arabia, Kuwait, and United Arab Emirates (UAE), regarding their significant dependence on fossil fuels in terms of feedstock for their energy systems and in terms of heavy dependence on oil revenues. The energy sector is the backbone of all GCC economies; thus, significant investments directed towards this sector, both downstream and upstream industries, specifically refineries, fertilisers, and petrochemicals.¹⁷¹

According to Asharf, there are some advantages of diversifying in the GCC's energy sectors, including modernisation of the energy industry that is the main sector of economy and main sources of revenue, size expansion of the industry, and diversification in different variety of oil products for domestic use and for export to international market. For example, the strategies of Qatar and Saudi Arabia have improved their crude oil production mixture by making different grades of crude oil such as heavy, medium, light, extra light and super light, while adding more value from crude oil by producing new products, including lubricants and chemicals.¹⁷²

The strategies implemented in most of the GCC countries have begun investing significantly in innovative technologies that have potential to modernise, increase capacity, and upgrade operational processes of the chemical and petrochemical industries in order to stay at their global competitiveness level. According to Aramco, diversification policy in the crude oil

¹⁷⁰ Byrne, J., Kurdgelashvili, L., Mathai, M., Kumar, A., Yu, J., Zhang, X., Tian, J., Rickerson, W. and Timilsina, G., 2010. World solar energy review: technology, markets and policies. *Washington, DC: Center for Energy and Environmental Policy of the University of Delaware, World Bank.*

¹⁷¹ Mas'ud, A. A. et al. (2018), Solar Energy Potentials and Benefits in the Gulf Cooperation Council Countries: A Review of Substantial Issues, *energies Review*, 2018, 11, 372, pp 1-20.

¹⁷² Mishrif, Ashraf., 2018. Industrialization and diversification strategies in the GCC countries.

industries, coupled with development of an integrated petrochemical and refining network would create flexibility in times of crude oil instability.¹⁷³

The national renewable energy strategies in GCC countries, on the other hand, have slightly introduced in their energy sectors by initiating sustainable resources such as wind, solar and biofuel, which reveals the growing awareness of environmental concerns about climate change. In addition, the GCC countries created a different range of solar energy programmes, with UAE taking the lead through some promising renewable energy projects, including Abu Dhabi's Shams Solar Park, which is recognised as the first utility-scale solar plant in the MENA. Furthermore, the Dubai Electrical and Water Authority (DEWA) have recently announced in their energy strategy the world's largest concentrated solar power facility, setting a world record with the cheapest price for a CPS power plant at just 7.3 cents/kWh.¹⁷⁴ HH Sheikh Mohammed Bin Rashid, Vice President and Prime Minister of the UAE and Ruler of Dubai, stated that "We will continue pursuing ambitious investments with an emphasis on projects that have a positive impact on people's lives. Clean and renewable energy is key to sustainable development and the UAE has set an example for its rapid adoption".¹⁷⁵ The UAE's vision is to have 44 percent of its energy coming from renewable resources by 2050. Qatar has invested in renewable energy projects, in regard to their new sports facilities and stadiums projects, with solar technology cooling for the football world cup 2022. Oman, Bahrain, Kuwait, and Saudi Arabi are also committed to the sustainable energy sector, with most of their projects are still under the research and development stage, with slight incorporation on limited scales. For instance, Saudi Arabia signed a five-year \$25 million partnership with the Massachusetts Institute of Technology (MIT) in 2018.¹⁷⁶ Table 2-3 depicts solar PV establishment in the GCC countries.

¹⁷³ Saudi Arabia Oil Company (Aramco) (2018). Available at: <https://www.saudiaramco.com/en/creating-value/products/chemicals>

¹⁷⁴ AWAD, Z., 2018. THE FIVE INDUSTRY SECTORS KEEPING THE GCC ON THE GLOBAL MAP, INDUSTRY RESEARCH, ENTREPRENEUR, JULY 30, 2018. AVAILABLE AT: <HTTPS://WWW.ENTREPRENEUR.COM/ARTICLE/317581>

¹⁷⁵ Acwapower.com. (2019). ACWA POWER | Mohammed bin Rashid breaks ground on world's biggest Concentrated Solar Power project. [online] Available at: <https://www.acwapower.com/en/newsroom/press-releases/latest-news/mohammed-bin-rashid-breaks-ground-on-world-s-biggest-concentrated-solar-power-project/> [Accessed 28 Mar. 2019].

¹⁷⁶ AWAD, Z., 2018. THE FIVE INDUSTRY SECTORS KEEPING THE GCC ON THE GLOBAL MAP, INDUSTRY RESEARCH, ENTREPRENEUR, JULY 30, 2018. AVAILABLE AT: <HTTPS://WWW.ENTREPRENEUR.COM/ARTICLE/317581>

Table 2- 3: Solar PV development in the GCC countries

Country	Solar Energy Target Share in Total Installed Capacity	Primary Energy Sources	Solar Insolation (kWh/m ² /Year)	Current Operational Solar Projects	Future Projects
Bahrain	5% of all renewable including solar (2020)	Oil, gas	2180	0.5 MW solar plant at the Bahrain university; 5 MWp Bapco pilot plant at Bapco.	5 MW solar project at Al Dur power and water plant
Kuwait	1% in 2015, 10% by 2020 and 15% by 2030.	Oil, gas	2200	Kuwait English School (Salwa). KISR's Solar House (Application Laboratory)	50 MW solar project across the country
Qatar	15% of all renewables with solar assimilated by 2018, and 20% by 2030.	Oil, gas	2113	Establishment of solar PV manufacturing plant in Ras Lafi.	Stadiums with solar technology cooling; 1000 MW solar PV plant in Doha.
Oman	10% by 2020.	Oil, gas	2500	Solar energy research in Oman is carried out by Sultan Qaboos University and Dhofar University	300 kW solar project at Al Mazyonah-Dhofar ;1000 kW solar project in Haima; 28 kW PV and storage system at Al Mathfa- Dhofar; 100 kW PV in Hijji.
KSA	54 GW from renewables including solar technology.	Oil, gas	2200	King Abdullah Petroleum Studies and Research Center Solar Park Riyadh; Saudi Aramco Solar Car Park Dhahran; King Abdullah University of Science and Technology Solar Park Thuwal; King Abdulaziz International Airport Development Project Jeddah.	1000 MW solar plant in Makkah; 10 MW Al-Khafji plant; 1.8 MW King Abdullah Petroleum studies and Research centre.
UAE	7% of all renewables by 2020, 25% 2030 and 75% by 2050.	Oil, gas	2285	Shams 1 in Western Abu Dhabi; Masdar city solar PV plant in Masdar city; Abu Dhabi solar rooftop program in Abu Dhabi government buildings; Murawah island PV plant Murwah island off the coast of UAE. Um Al-zomul off grid power plant Located at the desert (Um Al zomul)	1000 MW Mohammed bin Rashid Al Maktoum Solar Park.

Source: Mas'ud, A. A. et al, 2018.

The UAE launched its national energy strategy “Energy Strategy 2050” in 2017. This national strategy is considered the first unified energy strategy in the country, which aims to improve the contribution of the clean energy in the total energy mix from about 25 percent to reach 50 percent (44% renewable and 6% nuclear) by 2050 as well as reduces the carbon emissions by 70 percent. In addition, Masdar city in Abu Dhabi has been described as the most ambitious

sustainable development project in the world, with zero carbon and zero waste city power totally by renewable energy resources.¹⁷⁷

In 2018, the Crown Prince Mohammed bin Salman announced the construction of a large new business zone near the red sea by 2030, named “Neom”, Saudi Arabia’s Vision. The city is anticipated to be the “world’s most ambitious project” that marks the city as a hub for new industries and businesses as well as a way to develop jobs for young Saudis in energy sector. The city is projected to be pollution free and to operate totally on renewable energy.¹⁷⁸

The government of Kuwait aims to support the use of renewable energy in order to diversify the national energy mix, reduce greenhouse gas emissions, free up more oil for export, and generate new businesses and jobs. According to Xinhua, the adaption of renewable energy technologies could create savings of up to USD 750 million through 2030.¹⁷⁹ Currently, the Kuwaiti government sets a target of increasing the share of renewable energy to contribute 15 percent of the total energy mix by 2030 and 10 percent by 2020. In other words, it is anticipated that the installed capacity will come from CSP with 5.7 GW, solar PV 4.6 GW, and wind 0.7 GW.¹⁸⁰ In addition, several small-to mid-scale demonstration solar generation in recent years, with slightly gradual increases in size. For example, one of the most significant projects has been Shagaya, created by the Kuwait Institute for Scientific Research (KISR), producing 10 MW of solar PV, 50 MW of CSP, and 10 MW of wind capacity.¹⁸¹

Oman’s National Energy strategy 2040, jointly collaborated with IRENA’s Renewables Readiness Assessment¹⁸², was drafted in 2015 and submitted to the Council of Minister for

¹⁷⁷ Anon, (2019). [online] Available at: <https://government.ae/en/about-the-uae/strategies-initiatives-and-awards/federal-governments-strategies-and-plans/uae-energy-strategy-2050> [Accessed 28 Mar. 2019].

¹⁷⁸ Kalin, S., Nakhoul, S., and Robinson, S. (2017), “Exclusive: New Saudi mega-city will be listed publicly, crown prince says”, Reuters, 26 October, www.reuters.com/article/us-saudi-economy-mbs-interview-exclusive/exclusive-new-saudi-mega-city-will-be-listed-publicly-crownprince-says-idUSKBN1CV0ZM.

¹⁷⁹ Xinhua Net (2018), “Kuwait reaffirms commitment to renewable energy”, Xinhua Net, 7 May, www.xinhuanet.com/english/2018-05/07/c_137159921.htm.

¹⁸⁰ KUNA (Kuwait News Agency) (2018), “Kuwait eyes three pctshift from renewable energy by '20 – KISR”, KUNA, 23 January, www.kuna.net.kw/ArticleDetails.aspx?id=2685388&Language=en.

¹⁸¹ Ibid.

¹⁸² IRENA (2014a), Sultanate of Oman: Renewables Readiness Assessment, IRENA, Abu Dhabi.

approval. However, this strategy was not disseminated publicly or moved to the implementation phase.¹⁸³ On the one hand, the Rural Area Electricity Company (RAECO) has announced to develop renewable energy capacity of 90 MW by 2020.¹⁸⁴ Also, the AER launched the Sahim initiative, which was one of the most GCC's sophisticated and ambitious solar rooftop programme that supposed to attract industrial and residential sectors. Yet, this initiative has been slow due to high technology prices and subsidised electricity tariffs.¹⁸⁵ The Qatari government, Qatar's Second National Development Strategy 2018-2022, strives to increase their renewable energy use for 500 MW of solar power generation capacity by 2020.¹⁸⁶ In addition, the Ministry of Energy and Industry announced a long-term target of 10 GW of solar generation capacity by 2030, yet it has not been reflected into legislation.¹⁸⁷ As mentioned early, Qatar has announced targets to adopt solar power to cool the 2022 FIFA World Cup stadiums at a capacity of 3500 MW, but at later occasion, the announcement that the World Cup would be taking place in the winter months of November and December of 2022, with a significant reduction of solar power generation for the tournament's cooling needs.¹⁸⁸

In 2017 Bahrain, on the other hand, implemented the National Renewable Energy Action Plan (NREAP) and the National Energy Efficiency Action Plan (NEEAP). The NREAP identifies potential renewable energy options for the country, and recommends plans, policies and strategies for implementation. The target of the national renewable energy was set at 5% by 2025 and 10% by 2035. The diversification energy policy consists of solar, wind, and waste-to-energy technologies. In addition, the NEEAP sets a national energy efficiency target of 6% of the total electricity generation by 2025. The main purpose of this target is to improve

¹⁸³ Al Busaidi, A. (2019), Interview with Ahmed Al Busaidi, the Research Council, Oman, Muscat February 2019.

¹⁸⁴ Bellini, E. (2018a), "SirajPower develops 50 MW under DEWA's Shams Dubai initiative", www.pv-magazine.com/2018/10/10/sirajpower-develops-50-mw-under-dewas-shams-dubai-initiative/.

¹⁸⁵ Al Ghaithi, H. (2017), "Promoting Solar Rooftop in Oman policies, regulations & outlook", Muscat: Authority for Electricity Regulation Oman (AER).

¹⁸⁶ MDPS (Ministry of Development Planning and Statistics) (2018), Qatar Second National Development Strategy 2018- 2022, www.mdps.gov.qa/en/knowledge/Documents/NDS2Final.pdf.

¹⁸⁷ The Peninsula (2017), "Qatar to adopt first renewable energy strategy", The Peninsula, 27 November, www.thepeninsulaqatar.com/article/27/11/2017/Qatar-to-adopt-first-renewable-energy-strategy.

¹⁸⁸ Skysports (2018), "When and where is next World Cup? Qatar 2022 dates and key information", 21 November, www.skysports.com/football/news/12098/11558802/when-and-where-is-next-world-cup-qatar-2022-dates-and-key-information.

efficiency in both energy demand and supply through 22 programmes across all sectors of the economy.¹⁸⁹

2.7 Energy diversification policy perspectives from oil and gas importers and exporters

Growing concerns about the need for sustainable and safer energy sources necessitate changes in the manner in which energy is administrated, from production to the end user, thus concerning both the exporters and importers of oil and gas. Public awareness of the importance of the need to diversify energy into more sustainable resources and to reduce the adverse effects of pollutants and depletable resources, such as oil and gas, have gradually started to be acknowledged by policymakers across the world.¹⁹⁰ In fact, the different interests of the two sides (importers and exporters) of the oil and gas industry—which is currently the predominant source of energy—equate to social, economic, and environmental factors. However, a common understanding exists that there is an essential need for a change from the old conventional energy resources to the newer and more efficient technologies. Resources such as wind and solar power are needed to reduce not only environmental pollution and its associated effects such as climate change, but also to improve the energy efficiencies of countries to align with their national energy policies. Both energy importers and exporters are aware of the major aspects that must be factored into the course of energy diversification. These major development pillars comprise social capacity, economic goals, and environmental effects. Energy policies that incorporate all these perspectives are more sustainable than those that focus on only one. Therefore, every country is expected to view the way to energy diversification as a multidimensional path, rather than a one-element issue. Furthermore, energy policies need to address the challenges and factors in energy production that determine success or failure of diversification, such as technology, political will, human capital, and infrastructure development.¹⁹¹

¹⁸⁹ SEU (2017), “National Energy Efficiency Action Plan (NEEAP)”, www.seu.gov.bh/neeap/.

¹⁹⁰ Sovacool, B.K. and Brown, M.A., 2010. Competing dimensions of energy security: an international perspective. *Annual Review of Environment and Resources*, 35, pp.77-108.

¹⁹¹ Silva Jr, A.C., Andrade, J.C.S., Leao, E.B.D.S. and Wu, D.D., 2013. Sustainable development and cleaner technology in Brazilian energy CDM projects: consideration of risks. *Human and Ecological Risk Assessment: An International Journal*, 19(5), pp.1338-1358.

Although attaining the necessary technology is not a major problem for developed countries, it is one of the major obstacles to energy diversification in developing countries. For example, the ability to make massive investments in infrastructure for wind or solar power is determined by the ability of the country to source the equipment required. They must have the knowledge to deal with such technology and its equipment in order for the technology to work effectively and efficiently, and they must be able to maintain them afterwards.¹⁹² Political will is a major factor in both oil-exporting and oil-importing countries, and it influences the energy policy of the countries. The same applies for the supporting infrastructure such as electricity services, and the capacity to install new infrastructure. Therefore, formulation of energy policies requires that all aspects, described here and above, are factored into the policy details.

Policies from oil-importing countries are varied. They all require a comprehensive approach with cooperation of all sectors of the economy. Energy diversification for oil-importing countries not only needs to focus on the resources alone, but also efficient use of the available capacity, through minimising consumption and waste.¹⁹³ This policy framework applies well for all countries to reduce government spending in this area considerably. Therefore, it allows for surplus funds to be used in the development of diversified energy resources, such as the installation of solar panels and wind turbines as inexhaustible sources of energy.

Another approach by oil-exporting countries is to change the funding of energy-related projects and programmes from the mainstream oil and gas explorations to the production of renewable energy resources. This is a feasible policy framework that would not take long to implement in oil-exporting countries, given the high cost of investigating the presence of oil and gas and its ultimate extraction. In fact, the proportion of government budgets that go into investigation and extraction might not even be feasible to keep up in the long-term. It is important to start the process of diversification now and gradually shift to the more sustainable energy resources of wind, solar, or biofuel.¹⁹⁴ Another option for this policy framework is the use of government incentives, such as the allocation of subsidies for the development of diversified energy resources, at the expense of the subsidies for depletable oil and gas resources, which are

¹⁹² Rae, C. and Bradley, F., 2012. Energy autonomy in sustainable communities—A review of key issues. *Renewable and Sustainable Energy Reviews*, 16(9), pp.6497-6506.

¹⁹³ Ahuja, D. and Tatsutani, M., 2009. Sustainable energy for developing countries. *SAPI EN. S. Surveys and Perspectives Integrating Environment and Society*, (2.1).

¹⁹⁴ Dincer, I. and Rosen, M.A., 2012. *Exergy: energy, environment and sustainable development*. Newnes.

predominantly considered to be the driver of economies in oil-rich countries. This could be in the form of a reduction or even an elimination of subsidies for the oil and gas sectors. This policy framework has been designed and implemented, to a certain extent, by the oil-exporting countries, which are trying to learn how to diversify from the importing countries. The argument for the application of this type of policy is based on reducing dependence on oil and gas by introducing newer types of energy. In addition, oil-exporting countries are able to use the subsidies system to reduce the increased investment in the oil and gas sector, which is rising over time because of the increased difficulty of extraction. Importing countries do this, and invest more heavily in renewable resources, which improves the production of energy from diversified sources by research and development that advance technology and reduce costs.¹⁹⁵ The oil and gas exporters are, in most cases, the providers of technology and human capital that are necessary for the move to sustainable energy sources and have the benefit of supplying these to importers, instead of oil and gas. This aspect has never been exploited by the oil and gas-exporting countries as an alternative means of gaining income from importers. However, the oil and gas exporters are aware that clean and sustainable energy resources will increase their overall efficiency and boost their economic growth, compared with the commonly used oil and gas. Some of them have started the move towards diversified energy resources. In fact, major economic blocs, like the European Union, the Pacific region, Asia, and other oil and gas producers, are coming together to define common policies on energy diversification.¹⁹⁶

2.8 Political dimension of energy diversification

The political perspective on energy diversification rests on the political bargaining power of the oil-producing countries, such as the USA, the transatlantic trading bloc, north-eastern Asia (mainly China and Japan), member states of the European Union, and the GCC countries, including Oman. The oil-importing countries, including the majority of Africa and some Scandinavian countries, seem to have similar political viewpoints on energy exploitation and diversification and know that oil and gas are unsustainable. Although all of these regions might have different opinions and levels of political will towards a given course—ie, it is in the favour

¹⁹⁵ Fischhendler, I. and Nathan, D., 2014. In the name of energy security: the struggle over the exportation of Israeli natural gas. *Energy Policy*, 70, pp.152-162.

¹⁹⁶ Haselip, J., Al-Shafai, N. and Morse, S., 2010. EU energy security, sustainability and globalisation: What role for Qatari LNG amid calls for greater energy diversification?. *International Journal of Global Energy Issues*, 33(1-2), pp.38-55.

of the exporting countries for oil prices to increase, whereas importers would prefer low oil prices—as far as energy exploitation and diversification is concerned they seem to have a common ground in that they agree diversification is required, which helps them pull ideas and goals together, in order to realise a common outcome. This has been of substantial importance, especially in terms of the political will to encourage or discourage the move toward the diversification solutions for the local or regional energy. The oil-rich countries such as those in the GCC and the Middle East have shown less political will to diversify energy resources than other regions, including the European Union or the USA.¹⁹⁷ For example, GCC countries do not have any renewable energy types as part of their energy system. These differences are because of the differences in government priorities given that the climatic conditions (hot and dusty) in regions of GCCs and the Middle East could cause problems for certain renewable energy sources, and reduce the availability of energy options other than the predominant oil and gas energy.

For example, Oman and the rest of the GCCs are overly dependent on oil and gas as the sole source of funds, making it hard to reduce or remove these sectors, thus they tend to remain less in favour of divergence to other energy sources. On the other hand, other blocs such as the European Union that don't rely heavily on oil and gas revenue, use alternatives such as wind and solar power, which are supported by sound technology and a resource base. These differences in the priorities of the countries in terms of diversification of their energy resources relate back to the political orientations of either pro-energy diversification or anti-energy diversification.¹⁹⁸ However, some blocs or countries are oriented in between the two poles.

The bargaining power of the trading blocs or major countries that are involved in energy production, especially oil and gas, has not been similar across the board. Deni and Stegen demonstrated how political relationships in the transatlantic countries are shaped by their views on energy production and diversification.¹⁹⁹ The political views revolve around the individual interests of countries before they even consider themselves as a bloc or region that needs to

¹⁹⁷ Aslani, A., Naaranoja, M., Helo, P., Antila, E. and Hiltunen, E., 2013. Energy diversification in Finland: achievements and potential of renewable energy development. *International Journal of Sustainable Energy*, 32(5), pp.504-514.

¹⁹⁸ Fischhendler, I. and Nathan, D., 2014. In the name of energy security: the struggle over the exportation of Israeli natural gas. *Energy Policy*, 70, pp.152-162.

¹⁹⁹ Deni, J.R. and Stegen, K.S., 2012. Transatlantic energy security: convergence or divergence?. *Journal of Transatlantic Studies*, 10(4), pp.305-312.

work together toward a similar goal on energy security to achieve sustainability. The European Union and the USA have divergent views on energy diversification, showing that there is still no universal political will to have non-renewable energy resources replaced by more efficient and cleaner ones. Regardless, the political will among Arab countries has been strongly against energy diversification, because of the dependence on oil and gas for foreign exchange. There is some convergence of political will among the transatlantic partners such as the European Union and the USA, because of their ability to find newer and cleaner energy alternatives, supported by their strong economic and technological backgrounds.²⁰⁰ For example, the Arab countries that are major producers and exporters of oil and gas are found in the Middle East. These countries would have less conflicting issues to address, in terms of energy politics and resolutions, compared with the divergent views between the European Union and the GCCs. Before the pressure to diversify energy resources from the predominant oil and gas to more sustainable and green alternatives, the transatlantic countries had one political view of focusing on the stability of prices in the energy sector. Stegen and Kuszniir, reported as early as the 1970s that the countries of Europe and North America had realised the need for one political stand on issues of energy.²⁰¹ This has been an ongoing concern up to the present, as diversification of energy is sought. To achieve more energy sustainability, these countries intend to have a pro-energy-diversification political will. Recognition of the adverse effects of unwillingness to accept energy diversification, such as climate change, environmental degradation, and loss of biodiversity, forces them to continue towards energy diversification.²⁰²

The opposite can be said for the GCCs and the rest of the Arab world, in which monetary benefit from the oil and gas export revenues are prioritised over the long-term benefits of combatting climate change and environmental degradation. The overall effect is different political views on energy diversification throughout different regions of the world, and a consensus on the best way to diversify is far from being made. However, the call for global partnership in sustainable energy development, combined with the need for universal energy production efficiency and global trade could ultimately force convergence of the political

²⁰⁰ Cohen, G., Joutz, F. and Loungani, P., 2011. Measuring energy security: Trends in the diversification of oil and natural gas supplies. *Energy policy*, 39(9), pp.4860-4869.

²⁰¹ Stegen, K.S. and Kuszniir, J., 2012. Transatlantic energy relations: a view from Washington. *Journal of Transatlantic Studies*, 10(4), pp.313-327.

²⁰² King, M.D. and Gulledege, J., 2013. The climate change and energy security nexus. *Fletcher F. World Aff.*, 37, p.25.

divide on energy diversification, so that uniform energy milestones are achieved across the world.²⁰³ One way through which this could happen is by prosustainability regions such as the European Union and the United States putting pressure on other regions for sustainability, as described below.

Policies about energy diversification are strong in the energy-importing countries and the energy infrastructure supports renewables. Vivoda revealed that politics among oil importers has contributed substantially to adaption of energy diversification across the world.²⁰⁴ Scholars report that the importing countries value the availability of energy, such as increased commercialisation, industrialisation, and transportation, thus caring less about the source. Although this is true for all importing countries, some large importers like China, Japan, and the USA have now reduced their imports because of increased diversification and a large base of local resources. Using these politics of pro-diversification, the countries producing energy will be encouraged to also diversify as the importing countries rely on them less. China and the USA are countries that have significantly increased their energy diversification in terms of source and use; however, Japan relies heavily on imports of oil and gas from the Middle East as its dominant source of energy, which might be because there is less pressure on the government of Japan to diversify energy than in the other two major countries. Therefore, because some importers of oil and gas are encouraging production by the exporters, the move to energy diversification meets political barriers embedded in the policy framework on trade, technology, and production of goods and services.²⁰⁵

Local politics on energy diversification is complex between importers, exporters, trading blocs, and different regions of the world, and it seems that every country is affected by energy security issues. Politics is a precondition to the move to energy diversification that comes before the policy aspects. In fact, the political orientation of a country, trading bloc, or region with regards to energy sources and diversification shapes the policy framework that would either work for energy diversification or against it. This could also shift from time to time, with minimal deviation from the mainstream political ideology that is supported by the governments,

²⁰³ Ibid

²⁰⁴ Vivoda, V., 2009. Diversification of oil import sources and energy security: A key strategy or an elusive objective?. *Energy Policy*, 37(11), pp.4615-4623.

²⁰⁵ Sovacool, B.K. and Brown, M.A., 2010. Competing dimensions of energy security: an international perspective. *Annual Review of Environment and Resources*, 35, pp.77-108.

international agencies, and trading blocs. The move to energy diversification needs to address the political perspectives, thus allowing favourable policies that can be implemented to achieve the desired energy diversification outcomes.

2.9 Conclusion

This chapter presents a literature review providing a theoretical basis for this study. It started by reviewing the main concepts and concerns of energy diversification and how it defines energy diversification through different theories of variety, balance, and disparity. The chapter critically reviewed various aspects of renewable technologies to identify the importance of energy diversification in the context of developing countries, including Oman. In conclusion, the basis for this study is strongly supported by evidence showing the need for energy diversification. This is evidenced by various factors, including the oil production peak, which has led to concerns over the energy system's long-term survival; environmental issues such as the over-exploitation of natural and environmental resources; endangered energy security, including uncertainty of a continuous supply of energy resources to society; and the proven use of energy efficiency and conservation. In addition, renewable energy technologies are critically reviewed as one of the main players of energy portfolio.

Chapter 3

Conceptual and Theoretical Framework

3.1 Introduction

The focus of this research is to examine how energy sustainability policy impacts on the performance and behaviour of the energy sector of Oman. The study argues that the abundance and heavy dependence on non-renewable energy resources in oil-exporting countries can have both positive and negative effects. The positive aspect is that revenues are generated from oil exports, which enables a country to start developing. The negative impacts are that, as a result of perceived abundance of resources, no energy policy exists, domestic energy demand is high, energy resources are limited to non-renewable options and diversification to renewable resources has not occurred, and environmental protection has not been considered. This thesis argues that the negative effects of reliance on non-renewable energy markedly hinders the process of achieving energy sustainability.

Following the proposals of Huberman and Miles (1994),²⁰⁶ and the findings of various researchers on energy sustainability (Peake, Everett, Boyle, & Ramage, 2011;²⁰⁷ Rosen, 2009;²⁰⁸ Streimikiene & Šivickas, 2008;²⁰⁹ Version, 2010²¹⁰) and energy diversification (Bazilian, Roques, & Stirling, 2008;²¹¹ Stirling, 2010²¹²), a tentative conceptual framework can be established using insights from existing theories on energy sustainability and diversification of resources (chapter one Figure 1-1; complemented by inputs from the pilot research initiated for this study).

As Maxwell (2013)²¹³ stressed, building a conceptual framework for research before data collection can help to improve the preliminary study design that is reflected in a case-based

²⁰⁶ Huberman, A.M., Miles, M.B., 1994. *Qualitative Data Analysis: An Expanded Sourcebook*, Second Edition. ed. Sage Publications, Inc.

²⁰⁷ Peake, S., Everett, B., Boyle, G., & Ramage, J. (2011). *Energy Systems and Sustainability*, 672.

²⁰⁸ Rosen, M. A. (2009). Energy sustainability: A pragmatic approach and illustrations. *Sustainability*, 1(1), 55–80. <https://doi.org/10.3390/su1010055>

²⁰⁹ Streimikiene, D., & Šivickas, G. (2008). The EU sustainable energy policy indicators framework. *Environment International*, 34(8), 1227–1240. <https://doi.org/10.1016/j.envint.2008.04.008>

²¹⁰ Version, P. (2010). Energy and sustainability policies in the GCC Steffen Hertog and Giacomo Luciani, 44(August).

²¹¹ Bazilian, M., Roques, F., & Stirling, A. (2008). Chapter 1 – Diversity and Sustainable Energy Transitions: Multicriteria Diversity Analysis of Electricity Portfolios. In *Analytical Methods for Energy Diversity & Security* (pp. 1–29). <https://doi.org/10.1016/B978-0-08-056887-4.00001-9>

²¹² Stirling, A. (2010). Multicriteria diversity analysis. A novel heuristic framework for appraising energy portfolios. *Energy Policy*, 38(4), 1622–1634. <https://doi.org/10.1016/j.enpol.2009.02.023>

²¹³ Maxwell, J.A., 2012. *Qualitative research design: An interactive approach* (Vol. 41). Sage publications.

study. Huberman and Miles (1994)²¹⁴ noted that a qualitative investigator is at risk of delivering descriptions without meaning or of consuming much time collecting irrelevant information if the initial conceptual framework is ignored. However, if the pre-identified concepts of any framework are confirmed as the research progresses, then the research has a solid empirical grounding for the theory in question. However, according to Astalin (2013)²¹⁵, the purpose of an initial framework is not to restrict the data collection and analysis process to the key concepts in the framework, but rather to guide the research. In order to help achieve the objectives of this research, this chapter provides the conceptual and theoretical framework that will guide the process of data collection and analysis.

The discovery of fossil fuels (oil, gas, and coals) provides the financial means to speed up the socioeconomic development of a country. From one perspective, these resources are beneficial because the large revenues that are generated from commodity exports allow countries to develop and improve their social and economic structures, improving living standards. One exponent of this perspective is Stevens (2003)²¹⁶, who argues that the use of natural resources provides developing countries with the means to achieve more sustainable development if revenues are effectively managed; examples include Botswana, Norway, Chile, and Canada. In the case of the Gulf Cooperative Council (GCC) countries, oil revenues have been generally seen as a blessing because of huge investments, infrastructure projects, and overall national development. From a second perspective fossil fuel dependency is a resource curse²¹⁷ because countries with these abundant natural resources such as oil and natural gas often become dependent on the revenues from these resources, which are depletable and therefore not sustainable. Examples of countries where this effect has been experienced are the oil-exporting countries in the Middle East, specifically GCC countries such as Oman. The energy sectors in GCC countries are the dominant sectors fuelling overall development. The exploitation of oil and natural gas resources in many countries has led to them passing their point of peak oil²¹⁸

²¹⁴ Miles, M.B., Huberman, A.M., Huberman, M.A. and Huberman, M., 1994. *Qualitative data analysis: An expanded sourcebook*. sage.

²¹⁵ Astalin, P.K., 2013. Qualitative research designs: A conceptual framework. *International Journal of Social Science and Interdisciplinary Research*, 2(1), pp.118-124.

²¹⁶ Stevens, P., Lahn, G. and Kooroshy, J., 2015. *The resource curse revisited*. Chatham House for the Royal Institute of International Affairs.

²¹⁷ The resource curse can be defined as the failure of many resource- rich countries to benefit sustainably from their natural resource revenues.

²¹⁸ Peak oil refers to the point in time where oil production reaches its maximum production rate after which oil production gradually decline.

production; thus, the sustainability of supply is of great concern. Scholars have anticipated that in less than 20 years, some GCC countries will have entirely depleted their oil and natural gas resources, including Oman. As stated by Stevens, Lahn, & Kooroshy (2015):²¹⁹

“While natural resources may provide low-income countries with a significant development opportunity, serious risks are attached to a policy of growth based on their extraction, monetization and domestic consumption. The extractives-led growth consensus appears largely blind to those risks.”

Thus, energy sustainability policy is vital to secure socioeconomic achievements and move towards more sustainable and environmentally friendly energy practices²²⁰. According to Pearson & Watson (2012),²²¹ energy policy should not simply ensure constant supply of energy to match demand, but should also ensure and encourage sustainable production and use of energy resources to improve long-term quality of life and support diversification of energy resources to renewable and environment-conserving options and away from dependence on exhaustible oil and natural gas resources.

In the case of GCC countries, including Oman, the noticeable increases in local energy demand are attributed not only to population growth and economy expansion but also to subsidised energy prices, which allow residents to use energy at much cheaper rates than global market prices. Furthermore, consumption of oil and natural gas reserves is accelerated by the efforts of the GCC countries to maintain export levels despite increasing domestic energy demand. Thus, these efforts will eventually negatively affect socioeconomic development of these countries and prevent energy sustainability.

This study argues that the negative impacts on energy performance and sustainable development in oil-exporting countries are not just limited to general planning policies but also include factors such as energy policy, domestic energy demand, energy diversification, and environmental protection. This study assesses the four important factors in energy

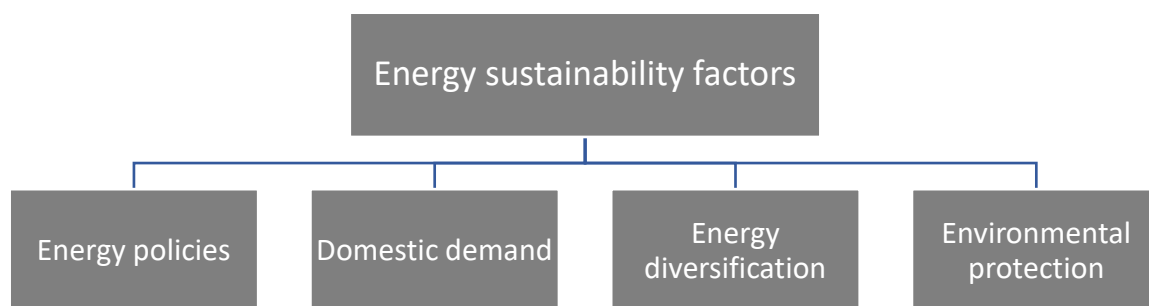
²¹⁹ Stevens, P., Lahn, G. and Kooroshy, J., 2015. *The resource curse revisited*. Chatham House for the Royal Institute of International Affairs.

²²⁰ A sustainability policy is not only dependent on economic dimension but also is dependent on social and political dimensions.

²²¹ Pearson, P. and Watson, J., 2012. UK Energy Policy 1980-2010: A history and lessons to be learnt.

sustainability: policy, domestic demand, diversification, and environmental protection (figure 3-1). To the knowledge of the author, no previous studies investigate the proposed factors of energy sustainability in Oman. Therefore, the contribution of this study is to develop the analysis of energy sustainability through a new model assessing the performance of the four energy sustainability factors. The four factors are interconnected and influence each other in different ways. In general, the author argues that the four factors are interconnected, while the results are likely to differ across countries.

Figure 3- 1: Energy sustainability factors



Source: compiled by the author

This chapter describes the energy sustainability theoretical framework used in this study. The chapter highlights how this study adopts energy diversification concepts and it also provides the key difference between resource abundance and resource dependence. In addition, the chapter identifies the energy sustainable measures such as affordability, availability, accessibility, and reliability. The chapter then focuses on the four energy sustainability factors.

3.2 Energy sustainability theory

The term sustainable development was first used by the International Union for Conservation of Nature and Natural Resources in its world conservation strategy in 1980.²²² One of the first definitions was given by Lester Brown in World Watch Institute in the early 1980s as “a

²²² Anand, S. and Sen, A., 2000. Human development and economic sustainability. *World development*, 28(12), pp.2029-2049.

sustainable society is one that can meet their needs without compromising the chances of survival of future generations”.²²³

However, in 1987, an influential definition was published in the Brundtland Report, which described sustainable development as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”²²⁴.

Most scholars and policy planners divide sustainable development into three main pillars of equal importance: social equity, economic development, and environmental protection.²²⁵ According to Najam and Cleveland (2003)²²⁶ energy sustainability policy is crucial in sustainable development and influences these three pillars²²⁷. For example, energy is the main driver of economic growth, because expansion in infrastructure and all related sectors of the economy such as building materials, industrial, transportation, tourism, and information and communication technology, require energy. Additionally, the use of fossil fuel resources (non-renewable energy) has adverse effects (carbon emissions and energy waste) on the environment. However, energy is an essential factor for many basic human needs and services, and therefore is indispensable.

The literature on energy sustainability highlights many approaches that could develop and improve energy sectors toward ultimately achieving sustainable development. As mentioned above, one important method of sustainable development is to link sustainable energy policy to the development of the economy, in a way that “meets the needs of the present generations without compromising the ability of future generations to meet their own needs” (WCED, 1987)²²⁸.

²²³ Brown, L.R., 1982. Building a sustainable society. *Society*, 19(2), pp.75-85.

²²⁴ Brundtland report was published in 1987 after 900 days of extensive work put together by different groups of politicians, industrialists, civil servants, scientist, and experts on environment and development. The report was the key statement of sustainable development and aimed to discuss the environment and development as one concern.

²²⁵ Drexhage, J. and Murphy, D., 2010. Sustainable development: from Brundtland to Rio 2012. Background paper prepared for consideration by the High Level Panel on Global Sustainability at its first meeting 19 September 2010.

²²⁶ Najam, A. and Cleveland, C.J., 2005. Energy and sustainable development at global environmental summits: an evolving agenda. In *The World Summit on Sustainable Development*(pp. 113-134). Springer, Dordrecht.

²²⁷ Ibid

²²⁸ Brundtland report was published in 1987.

Maite (1995) categorised sustainability into two conceptual approaches: weak and strong sustainability²²⁹. The idea of weak sustainability is that natural capital (natural resources that generate goods and services) can be substituted by manmade goods and services (manufactured materials) without decreasing the total stock of natural capital for future generations.²³⁰ In other words, finite natural resources such as fossil fuels (non-renewable resources) can be used and then replaced partially with manmade technologies such as renewable resources (solar, tidal, wind, and other forms of renewable energy). Weak sustainability, as a result, can be used as long as the natural capital is substitutable. However, some scientists argue that it is difficult to value some types of natural capital, especially those resources that are close to extinction or which cannot be replaced, such as oil and natural gas. Therefore, it might not be possible to replace the lost value of these natural resources with renewable energy sources²³¹.

By contrast, strong sustainability is the foundation of human survival and development, and its natural capital cannot be replaced or duplicated by manmade capital. The natural capital has its own unique characteristics and performs in such a way that people cannot mimic. For example, in terms of the depletion of the ozone layer, weak sustainability might indicate that gains from activities that caused the depletion outweigh the value of the ozone layer, but strong sustainability indicates that the loss of the ozone layer cannot be fixed or substituted by financial gain. Another important difference between strong sustainability and weak sustainability is its focus on human demand on resources (such as energy) and how they could be adapted to existing resources, rather than just trying to create more resources to keep up with demand. In other words, although weak sustainability focuses on potential abilities to replace the current resources with alternatives, the strong sustainability argument stresses the need to control human use to preserve the resources (eg, energy per capita and behaviour changes). Hence, on the scale of sustainability types, weak sustainability with resource expansion is on one side, whereas strong sustainability controlling human demands for resources is on the other side. From these two types comes the third approach to sustainability, moderate sustainability. The moderate approach looks at both sides of the argument. It argues that to maintain a comprehensive level of sustainability, simultaneous expansion of existing

²²⁹ Gutés, M.C., 1996. The concept of weak sustainability. *Ecological economics*, 17(3), pp.147-156.

²³⁰ Sustainablemeasures.com. (2017). *Weak Sustainability*. [online] Available at: <http://sustainablemeasures.com/Training/Indicators/WeakStrg.html> [Accessed 20 Sep. 2018].

²³¹ Beckerman, W., 1994. 'Sustainable development': is it a useful concept?. *Environmental values*, 3(3), pp.191-209.

resources and control of human demand is needed²³². In this research, moderate sustainability is considered the ideal option, for creation of greater balance. Based on the above discussion, the term energy diversification is used for moderate sustainability for the purpose of this research.

3.2.1 Energy diversification: definition and theories

One of the fundamental justifications for the diversification of energy resources is captured by the proverb “don’t put all your eggs in one basket”.²³³ In other words, the value of diversification lies in spreading dependencies across a variety of different baskets, with the hope that, even if some of the attempts fail, others will prevail. However, it is not always clear what the contents of any individual basket should be. Diversity has been used to strengthen a wide range of fields and disciplines, but Stirling argued that the proper definition of diversity is often misunderstood.²³⁴ Some researchers have applied diversity as an instrument to mitigate risks, but Stirling argued that the practical value of diversity is in offering a strong response to the most intractable form of uncertainty, ignorance, and ambiguity where precisely these probabilistic tools are not applicable. Therefore, Stirling argued that ignorance, risk, and uncertainty have three different meanings and require three different answers. Stirling emphasised that risk occurs when probabilities cannot be allocated to each of a well recognised set of possible outcomes. When risks arise, the best applicable mitigation strategy might be using Bayesian distribution functions or other probability tools.²³⁵ Uncertainty occurs when there are no grounds for assigning probabilities to define outcomes.²³⁶ Stirling supported this by stating “the general treatment of uncertainty as if it were mere risk offers a prime example of what Hayek once lamented as the pretence of knowledge in economics.”²³⁷ When uncertainty arises, analysis of a scenario can be used”.²³⁸

²³² Williams, C.C. and Millington, A.C., 2004. The diverse and contested meanings of sustainable development. *Geographical Journal*, 170(2), pp.99-104.

²³³ Grubb, M., Butler, L. and Twomey, P., 2006. Diversity and security in UK electricity generation: The influence of low-carbon objectives. *Energy policy*, 34(18), pp.4050-4062.

²³⁴ Stirling, A., 2010. Multicriteria diversity analysis: a novel heuristic framework for appraising energy portfolios. *Energy Policy*, 38(4), pp.1622-1634.

²³⁵ Jaynes, E.T., 1986. Bayesian methods: General background.

²³⁶ Werner, R.R., 2010. *Designing strategy: the art of scenario analysis*. Windjammer Adventure Publishing.

²³⁷ Hickey, E.A., Carlson, J.L. and Loomis, D., 2010. Issues in the determination of the optimal portfolio of electricity supply options. *Energy Policy*, 38(5), pp.2198-2207.

²³⁸ Werner, R.R., 2010. *Designing strategy: the art of scenario analysis*. Windjammer Adventure Publishing.

Finally, diversity might best be applied only when investment decisions are characterised by ignorance, which differs from risk or uncertainty. Stirling defines ignorance as a state in which the policymaker is not only unable to assign probabilities to a set of outcomes, but also is unaware of the possible outcomes.²³⁹ He also argued that when looking into investments in electricity generation, ignorance and strict uncertainty—rather than risk—characterise the policy-making process.

Because the definition and purpose of energy diversity often varies, there is no consensus on the way that diversity should be implemented, both in energy policy decision making and the related analysis by researchers. International policy debates about energy diversification are all in various ways aiming for “an evenly balanced reliance on a variety of mutually disparate options”.²⁴⁰ Stirling suggested that the diversity of a system can be divided into three further basic elements (variety, balance, and disparity), but each is not individually sufficient for diversity.

The first element is variety, which refers to the number of diverse categories of energy options into which an energy system might be partitioned. This measure of diversity is simply the number of different energy categories used—eg, oil, coal, gas, nuclear, or renewable energy such as wind or solar energy. Assuming all categories are equally weighted, the greater the number of different types of energy option (i.e., the variety), the greater the system diversity.²⁴¹ For example, in 1991, the International Energy Agency (IEA) reported that the electricity supply systems in member states of the Organization for Economic and Co-operation and Development (OECD) consisted of six options, including oil, gas, coal, nuclear, geothermal, and hydro power.²⁴² One decade later, the report showed an increase to ten options, adding resources from solar, wind, wave, combustible renewables, and waste to the mix.²⁴³

Balance is the second of Stirling’s elements, and refers to the distribution of options in the energy system. It refers to the levels of dependence on each option. Balance can be measured

²³⁹ Stirling, A., 2010. Multicriteria diversity analysis: a novel heuristic framework for appraising energy portfolios. *Energy Policy*, 38(4), pp.1622-1634.

²⁴⁰ Sovacool, B.K. ed., 2010. *The Routledge handbook of energy security*. Routledge.

²⁴¹ Stirling, A., 2010. Multicriteria diversity analysis: a novel heuristic framework for appraising energy portfolios. *Energy Policy*, 38(4), pp.1622-1634.

²⁴² International Energy Agency, 2015. Excerpt from: Electricity Information 2015, in: Electricity Information 2015. p. 894. doi:10.2307/821459

²⁴³ Ibid.

in terms of the energy input needed or output provided by that source, its power capacity, number of countries that the energy is sourced from, or economic values—i.e., the proportion of the economy to which each type contributes. Assuming that all categories are equal in terms of how much energy they provide, the more even the balance of energy options, the greater the energy system diversity. An example of the importance of considering balance occurred in Japan and France after the oil shock in 1973. Both Japanese and French electricity supply systems moved away from oil-based systems in which nuclear electricity generation was low (Japan: 2% nuclear and 98% oil. France: 8% nuclear and 92% oil). The diversification strategy implemented in response to the shock included, in Japan, an almost even balance across coal, gas, and nuclear energy options.²⁴⁴ However, in France, the strategy comprised a 40% dependence on oil and 60% on nuclear energy, without expanding to multiple energy sources, which would have made the system more stable.²⁴⁵

The third element is disparity, which refers to the nature and degree to which the energy options are different from each other.²⁴⁶ For example, oil and gas are closely related to each other in terms of technology use and fuel prices, whereas solar and nuclear are not. Assuming all categories as equally different to each other, the more disparate the energy options, the greater the energy system diversity. However, not all energy options are equally different, and so, for example, an electricity generation system broken down equally among oil, gas, solar, wind, nuclear, and geothermal power is more disparate than a system broken down equally among coal, oil, and gas.²⁴⁷

However, the case of oil-exporting countries in the Middle East, particularly those in the GCC such as Oman, is different to oil-importing countries. Energy diversification targets have been set at national or local levels, yet implementation has been negligible.²⁴⁸ This is mainly attributed to oil abundance in these countries, which resulted in a heavy reliance on oil. According to the BP statistical review of the world energy 2016, GCC countries jointly hold

²⁴⁴ Suzuki, T., 2000. Energy security and the role of nuclear power in Japan. *Nautilus Institute*, online:<http://oldsite.nautilus.org/archives/energy/eaef/Reg_Japan_final.PDF>(25.05. 2011).

²⁴⁵ Skea, J., 2010. Valuing diversity in energy supply. *Energy Policy*, 38(7), pp.3608-3621.

²⁴⁶ Stirling, A., 2010. Multicriteria diversity analysis: a novel heuristic framework for appraising energy portfolios. *Energy Policy*, 38(4), pp.1622-1634.

²⁴⁷ Ibid.

²⁴⁸ Griffiths, S., 2017. Renewable energy policy trends and recommendations for GCC countries. *Energy Transitions*, 1(1), p.3.

29% of the world's oil reserves, and 22% of the world's natural gas.²⁴⁹ Such abundance of oil and gas might have made the future appear sustainable.

In addition to the abundance of oil and natural gas in the GCC, domestic oil and natural gas prices are very low compared with the international oil market because of subsidies. These subsidies increase local energy consumption and hinder the competitiveness of renewable energy resources in these countries. According to Ada (2017),²⁵⁰ domestic energy demand has been growing at an average rate of 6% per annum since 2000, and this is mainly attributed to the following trends:

- Development of industries that are inherently energy intensive.
- Low energy prices (subsidies) have discouraged the adoption of energy efficiency and conservation measures, resulting in a higher per capita energy consumption in GCC countries than the rest of the world.
- Increasing electricity needs. GCC countries are projected to increase electricity consumption by at least 40% in the next 10 years. In fact, the increasing demand for domestic electricity has made some GCC countries net importers of natural gas.

Thus, if domestic energy consumption in the GCC region remains high or is not fulfilled by alternative energy resources, domestic consumption could use up most of the fossil fuels produced in the GCC over the next 20 years. In this scenario, GCC countries would not only be restricted from exporting oil but would not meet their own domestic energy demand. This forecast is mainly attributed to the absence of appropriate planning policies ahead of the fall in oil production (oil depletion).

In summary, the energy sectors in GCC countries, including Oman, are not heading in a sustainable direction and immediate action is needed to pursue energy efficiency and conservation as well as diversification of energy mix through increasing investments in renewable energy resources. According to Cherif & Hasanov (2014),²⁵¹ a diversified energy mix would reduce carbon dioxide (CO₂) emissions, free up fossil fuels for export, foster

²⁴⁹ BP London, 2016. BP Statistical Review of World Energy June 2016.

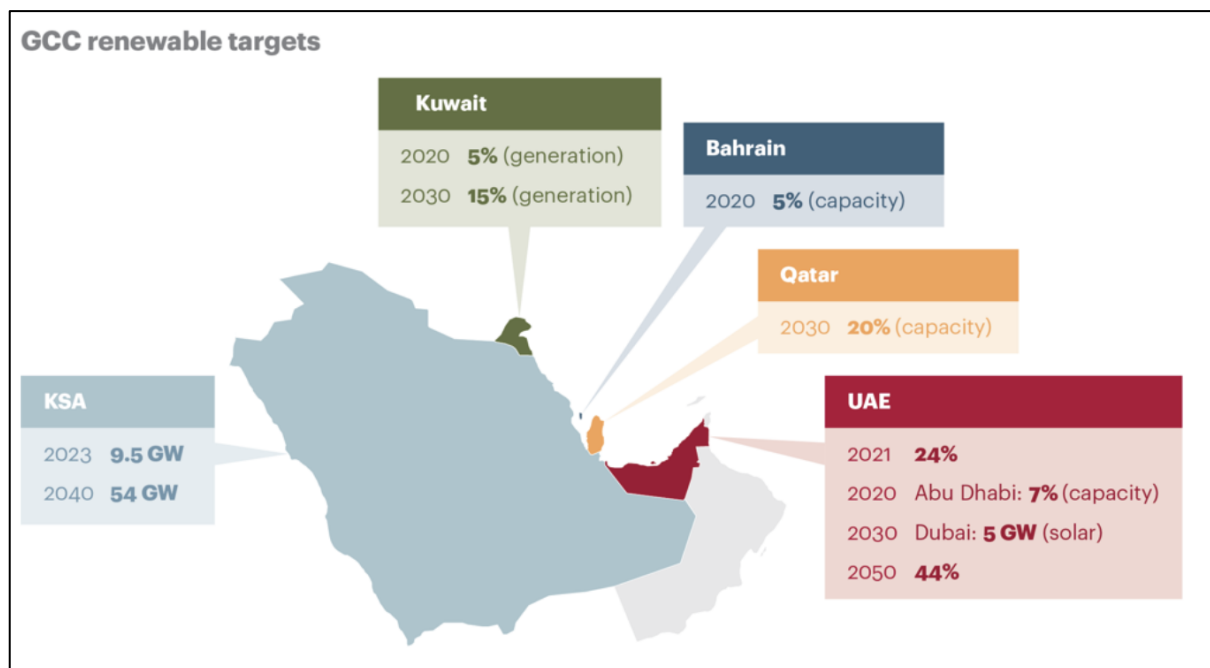
²⁵⁰ Perniceni, A. (2017). *Why oil-rich Gulf countries need to invest in renewable energy*. [online] World Economic Forum. Available at: <https://www.weforum.org/agenda/2017/05/why-oil-rich-gulf-countries-need-to-invest-in-renewable-energy/> [Accessed 20 Sep. 2018].

²⁵¹ Shafiei, S., & Salim, R. A. (2014). Non-renewable and renewable energy consumption and CO₂ emissions in OECD countries: A comparative analysis. *Energy Policy*, 66, 547–556. <https://doi.org/10.1016/j.enpol.2013.10.064>

economic development, and accelerate the process of strategically vital job creation within the GCC.

Most GCC countries have announced plans to invest in renewables and have agreed upon goals to be achieved by 2040. However, in Oman, no clear plan for targets have been made²⁵² (figure 3-2; Ada's report).²⁵³

Figure 3- 2: The GCC countries' plans to invest in renewables by 2040



Source: Ada Perniceni (2017)

To understand why energy sustainability is more associated with renewable resources, it is important to identify the main difference between renewable and non-renewable resources (finite resources). The difference can be defined on the basis of carbon emissions, usage life, availability, capital investment required, maintenance costs, and environmental effects. Accordingly, the first difference is that non-renewable resources (oil, natural gas, and coal) are limited, and thus will be depleted eventually. Thus, because non-renewable resources deplete, their impact on the energy sector is not sustainable. By contrast, renewable resources (e.g., solar and wind power) can be continuously consumed by people and renewed by nature. Shafiei

²⁵² Oman has initiated one pilot project in solar energy at PDO for the purpose of oil extraction, yet there is not clear plan to include the share of such technology in the energy system as a feedstock to generate electricity.

²⁵³ Perniceni, A. (2017). *Why oil-rich Gulf countries need to invest in renewable energy*. [online] World Economic Forum. Available at: <https://www.weforum.org/agenda/2017/05/why-oil-rich-gulf-countries-need-to-invest-in-renewable-energy/> [Accessed 20 Sep. 2018].

& Salim (2014)²⁵⁴ highlighted the main differences between renewable and non-renewable energy resources in the following table:

Table 3- 1: Main differences between renewable and non-renewable energy resources

Renewable energy resources	Non-renewable energy resources
They can be re-consumed again and again through their life time	They cannot be re-generated once consumed
They cannot be depleted, and are thus infinite	They are finite and will eventually be exhausted
They have low carbon footprint, do not produce pollution, and hence are environmentally friendly	They have high carbon emissions and hence are not environmentally friendly
Initial costs of these resources are reasonable and technologies are becoming cheap	Initial costs are high. Oil and natural gas extraction are very expensive processes
Low maintenance costs	High maintenance costs
International market prices are decreasing	International market prices are fluctuating and unpredictable
Encourages nature and natural processes of the earth	Disrupts the balance in the nature, because of the digging process in the earth to extract oil and natural gas

Source: Shafiei & Salim (2014)

Non-renewable energy resources are depletable, and thus their supply is limited. The demand for these resources is increasing substantially, and currently, consumption outweighs production. According to Chapman and Roberts (1983)²⁵⁵ and Reijnders (2000)²⁵⁶, natural resources can be classified into three main types: continuous resources whose availability does not reduce regardless of use, such as wind and sunlight; renewable resources that take longer to be regenerated than the time taken to harvest them such as crops and wood; and non-

²⁵⁴ Shafiei, S., & Salim, R. A. (2014). Non-renewable and renewable energy consumption and CO2 emissions in OECD countries: A comparative analysis. *Energy Policy*, 66, 547–556. <https://doi.org/10.1016/j.enpol.2013.10.064>

²⁵⁵ Chapman, P. F., & Roberts, F. (1983). *Metal Resources and Energy*. *Metal Resources and Energy*. <https://doi.org/10.1016/B978-0-408-10801-0.50009-2>

²⁵⁶ Reijnders, L. (2000). A normative strategy for sustainable resource choice and recycling. *Resources, Conservation and Recycling*. [https://doi.org/10.1016/S0921-3449\(99\)00037-3](https://doi.org/10.1016/S0921-3449(99)00037-3)

renewable resources that cannot be regenerated once used, such as oil and natural gas. The theory of non-renewable resources is also confirmed by Twidell and Weir (2015)²⁵⁷ who stated that non-renewable resources will deplete and future generations will not have the benefits of fossil fuels. Non-renewable resources should be preserved for future generations, because current renewable technologies would not provide sufficient energy without the input of some fossil fuels. Therefore, renewable and non-renewable energy resources need to be used in combination, and sustainability of energy resources must be encouraged.

These factors should rationally be a driver for energy diversification in the oil-rich countries (Griffiths, 2017).²⁵⁸ However, the resource curse theory focuses on the concerns of resource dependence and abundance and does not offer a clear understanding of how to avoid the negative effects of these. This might be partly because of the misguided use of concepts of resource dependent and resource abundant in the resource curse theory.

3.2.2 Resource abundance and resource dependence

As highlighted by Brunnschweiler and Bulte (2008),²⁵⁹ one of the criticisms of the resource curse theory is that it does not differentiate between natural resource abundance and natural resource dependence. This is because resource dependence focuses on the level of a country's reliance on natural energy resources such as fossil fuels. Dependence can be measured as the percentage contribution of resources to a country's energy portfolio or GDP. For example, all GCC countries are highly dependent on their fossil fuel sector not only to meet their local energy demands but for oil export revenues. In the case of Oman, in 2016, 70% of total government revenues came from oil exports, whereas in terms of local energy demand, 97.5% was met by use of oil and 2.5% by natural gas.²⁶⁰ However, resource abundance focuses on the endowment of natural resources and is usually assessed by measuring the natural resource

²⁵⁷ Twidell, J. and Weir, T., 2015. *Renewable energy resources*. Routledge.

²⁵⁸ Griffiths, S. (2017). Renewable energy policy trends and recommendations for GCC countries. *Energy Transitions*, 1(1), 3. <https://doi.org/10.1007/s41825-017-0003-6>

²⁵⁹ Brunnschweiler, C. N., & Bulte, E. H. (2008). The resource curse revisited and revised: A tale of paradoxes and red herrings. *Journal of Environmental Economics and Management*, 55(3), 248–264. <https://doi.org/10.1016/j.jeem.2007.08.004>

²⁶⁰ Hariharan, A. (2017). *Analysis of Oman's 2017 budget*. [online] KPMG. Available at: <https://home.kpmg.com/om/en/home/insights/2017/01/2017omanbudget.html> [Accessed 20 Sep. 2018].

capital per capita. Hence, resource abundance does not by definition cause a negative impact on energy or economic sector performance, unlike resource dependence.

Resource-dependent countries are influenced by the resource curse because the discovery of oil and natural gas in most of these countries occurred when they were in an early phase of socioeconomic development.²⁶¹ At the same time, demand for natural resources increased around the world, putting the focus of the energy sector on investments and export.²⁶² Furthermore, GDP in resource-abundant countries has increased rapidly because of the level of oil extraction and international oil prices. Despite fluctuating in energy prices that have negatively affected the economy of exporting countries, resource-abundant countries remain heavily dependent on the export revenues, confirming that they are resource dependent.

Auty and Warhurst (1993)²⁶³ defined mineral-based economies as “economies which generate at least 10% of their GDP from mining and at least 40% of their foreign exchange earnings from mineral exports”. However, some scholars (Stevens et al., 2015;²⁶⁴ Frankel, 2010;²⁶⁵ and Al-Rawashdeh, Al-Nawafleh, and Al-Shboul, 2013²⁶⁶) define resource dependence as 60–95% of total exports. Other definitions use 25%.²⁶⁷ According to all of these different definitions, over the past four decades Oman has been resource dependent because oil exports were around 60% of total exports and generated 45–86% of government revenues.²⁶⁸ Figure 3-3 presents the dependency of Omani government on oil revenues.

²⁶¹ The discovery of natural resources in Countries such as Canada, Norway, Australia, USA, and Botswana did not have adverse effects on their socioeconomic structure because those countries were already in the middle to high income per capita.

²⁶² Lahn, G., Stevens, P. and Preston, F., 2013. *Saving oil and gas in the gulf*. Chatham House.

²⁶³ Auty, R., & Warhurst, A. (1993). Sustainable development in mineral exporting economies. *Resources Policy*. [https://doi.org/10.1016/0301-4207\(93\)90049-S](https://doi.org/10.1016/0301-4207(93)90049-S)

²⁶⁴ Stevens, P., Lahn, G. and Kooroshy, J., 2015. *The resource curse revisited*. Chatham House for the Royal Institute of International Affairs.

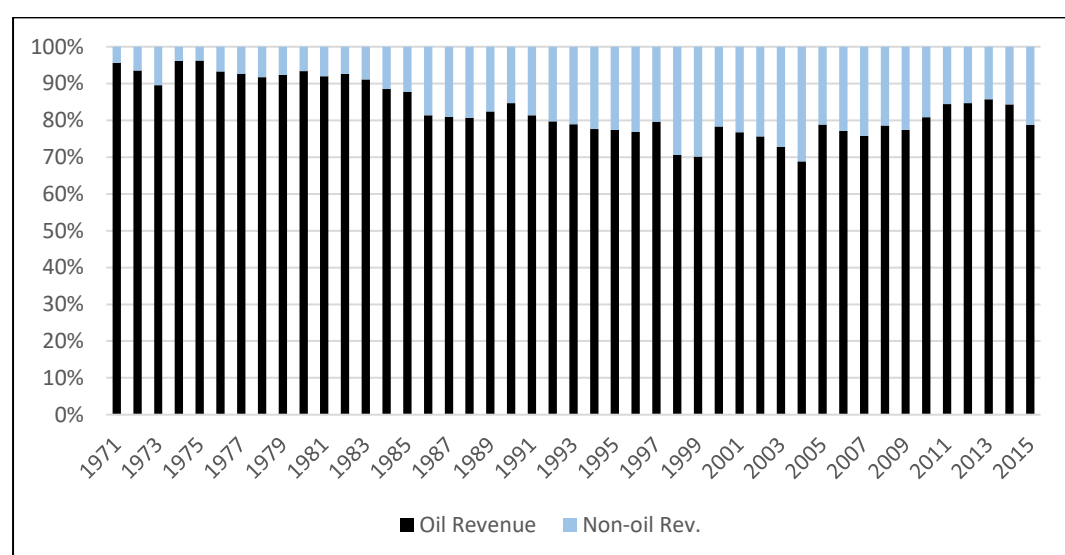
²⁶⁵ Frankel, J. A. (2010). The Natural Resource Curse: A Survey. *Beyond the Resource Curse*. <https://doi.org/10.2139/ssrn.1565588>

²⁶⁶ Al-Rawashdeh, R., Al-Nawafleh, H. and Al-Shboul, M., 2013. Understanding oil and mineral resources in a political economy context: the case of the Middle East and North Africa (MENA). *Mineral Economics*, 26(1-2), pp.13-28.

²⁶⁷ Karl, T.L., 2007. Oil-led development: social, political, and economic consequences. *Encyclopedia of energy*, 4, pp.661-672.

²⁶⁸ NCSI (2015) Statistical yearbook. Muscat: National Centre for Statistics and Information.

Figure 3- 3: Omani government revenues from the oil and non-oil sectors (1971-2015)



Source: Compiled by the author using data gained from the World Bank, 2016.

The data clearly confirm that Oman is an oil-dependent country, and therefore vulnerable not only to the resource curse but also to resource depletion, because of the finite availability of energy resources and the extraction rate of these resources, which do not serve overall energy sustainability.

It is important to distinguish between natural resource use and energy performance. Since the discovery of oil and natural gas, Oman's oil and natural gas extraction has increased, which increased the GDP growth rate. However, this growth does not necessarily suggest that Oman has achieved good energy performance in terms of sustainability. Oil reserves have remained the same in terms of available stock since the 1970s but the extraction rate has increased greatly because of the advancement of technologies such as enhance oil recovery techniques, which causes a reduction in the total available oil underground. According to BP's Statistical Review of world energy (2017), Oman holds 5.4 billion barrels of proven oil, which is estimated to last for the next 15 years.²⁶⁹ In addition, the level of oil extraction increased from 121 million barrels per year in 1970 to 360 million barrels per year in 2015.²⁷⁰ Oil is the main natural resource that Oman uses in its energy sector, with no clear consideration of others.

²⁶⁹ BP London, 2017. BP Statistical Review of World Energy June 2017.

²⁷⁰ NCSI (2016) Statistical yearbook. Muscat: National Centre for Statistics and Information

3.2.3 Energy sustainability measures

The literature offers many ways of measuring energy sustainability under the criteria of economic resources, environmental impact, and social performance as well as political dimension. However, the most common energy sustainability measures are affordability, availability, accessibility, and reliability. These four factors are the key driving force for energy policy and can determine whether a country is considered as moving in the right direction regarding sustainable development. However, research on sustainable development focuses mainly on the oil-importing countries (Asif and Muneer, 2007;²⁷¹ Cherp and Jewell, 2014;²⁷² Vivoda, 2009²⁷³) and is considered as an energy security issue. For example, the IEA (2010) defined energy security as “the uninterrupted physical availability at a price which is affordable, while respecting environment concerns”. The World Energy Council identified the three ‘A’s, which are accessibility to modern, affordable energy for all, availability in terms of sustainability of supply and reliability of services, and acceptability in terms of social and environmental goals.²⁷⁴ The Asia-Pacific Energy Research Centre described a similar theory but with four measures, called the four ‘A’s, which are availability in terms of fossil fuels (oil and natural gas), accessibility in terms of the hurdles to accessing the energy resources, affordability of energy in terms of fuel prices and infrastructure costs, and acceptability surrounding environmental matters focusing on greenhouse gas emissions.²⁷⁵

Unlike energy-importing countries that largely focus on energy security of supply, for energy-exporting countries, energy security means a stable energy export flow at a sufficient price that can ensure new energy investment projects and general socioeconomic development. In other words, energy-exporting countries require security of demand as part of their energy security. This was evident when the oil price collapsed in 1986, 1998, 2009, and 2014, during which,

²⁷¹ Asif, M. and Muneer, T., 2007. Energy supply, its demand and security issues for developed and emerging economies. *Renewable and Sustainable Energy Reviews*, 11(7), pp.1388-1413.

²⁷² Cherp, A. and Jewell, J., 2014. The concept of energy security: Beyond the four As. *Energy Policy*, 75, pp.415-421.

²⁷³ Vivoda, V., 2009. Diversification of oil import sources and energy security: A key strategy or an elusive objective?. *Energy Policy*, 37(11), pp.4615-4623.

²⁷⁴ Caillé, A., Al-Moneef, M., de Castro, F.B., Bundgaard-Jensen, A., Fall, A., de Medeiros, N.F., Jain, C.P., Kim, Y.D., Nadeau, M.J., Testa, C. and Teyssen, J., 2007. Deciding the future

²⁷⁵ APERC, A., 2007. Quest for Energy Security in the 21st Century: Resources and Constraints. *Asia Pacific Energy Research Centre, Tokyo, Japan*.

oil-exporting countries faced a significant fall in their oil export revenues.²⁷⁶ According to Yergin, security of demand refers to “stable commercial relations with their customers, whose purchases often provide a significant part of their national revenues”.²⁷⁷ In this context, energy availability, affordability, accessibility, and reliability are viewed differently in oil-exporting countries compared with in oil-importing countries. Therefore, natural resource use and energy performance might vary between countries depending on country-specific circumstances, national energy priorities and objectives, and sustainability and development standards.²⁷⁸

3.3 Energy sustainability factors

Building on the literature review in chapter 2, this study proposes that four interrelated factors influence the energy sector and whether it achieves energy sustainability. These factors are policies, domestic demand, diversification, and environmental protection. As the literature review highlighted, there are strong conceptual and theoretical foundations (APERC, 2007;²⁷⁹ Brown and Sovacool, 2007;²⁸⁰ Gnansounou, 2008;²⁸¹ Hughes, 2012;²⁸² Jansen, Arkel, and Boots, 2004;²⁸³ Kemmler and Spreng, 2007;²⁸⁴ Kruijt, van Vuuren, de Vries, and Groenenberg, 2009;²⁸⁵ Neves and Leal, 2010;²⁸⁶ Streimikiene and Šivickas, 2008²⁸⁷) to suggest these four factors do affect the transition to energy sustainability.

²⁷⁶ Secretariat, E.C., 2015. International energy security—a common concept for energy producing, consuming and transit countries. *Energy Charter Secretariat, Brussels*.

²⁷⁷ Cohen, A., 2007. Foreign Policy and National Security Implications of Oil Dependency. *The House of Foreign Affairs Committee*, p.8.

²⁷⁸ Vera, I. and Langlois, L., 2007. Energy indicators for sustainable development. *Energy*, 32(6), pp.875-882.

²⁷⁹ APERC, A., 2007. Quest for Energy Security in the 21st Century: Resources and Constraints. *Asia Pacific Energy Research Centre, Tokyo, Japan*.

²⁸⁰ Brown, M.A. and Sovacool, B.K., 2007. Developing an 'energy sustainability index' to evaluate energy policy. *Interdisciplinary Science Reviews*, 32(4), pp.335-349.

²⁸¹ Gnansounou, E., 2008. Assessing the energy vulnerability: Case of industrialised countries. *Energy Policy*, 36(10), pp.3734-3744.

²⁸² Hughes, L., 2012. A generic framework for the description and analysis of energy security in an energy system. *Energy Policy*, 42, pp.221-231.

²⁸³ Jansen, J.C., Arkel, W.V. and Boots, M.G., 2004. Designing indicators of long-term energy supply security.

²⁸⁴ Kemmler, A. and Spreng, D., 2007. Energy indicators for tracking sustainability in developing countries. *Energy policy*, 35(4), pp.2466-2480.

²⁸⁵ Kruijt, B., van Vuuren, D.P., de Vries, H.J. and Groenenberg, H., 2009. Indicators for energy security. *Energy policy*, 37(6), pp.2166-2181.

²⁸⁶ Neves, A.R. and Leal, V., 2010. Energy sustainability indicators for local energy planning: Review of current practices and derivation of a new framework. *Renewable and Sustainable Energy Reviews*, 14(9), pp.2723-2735.

²⁸⁷ Streimikiene, D. and Šivickas, G., 2008. The EU sustainable energy policy indicators framework. *Environment International*, 34(8), pp.1227-1240.

3.3.1 Energy policies

According to Pohekar and Ramachandran (2004),²⁸⁸ oil-exporting countries face serious energy policy problems, which influence not only their energy sustainability but also their economic performance at the national level. The problems include the absence of integration of sustainable energy policies into national development strategies, insufficient planning policies during their implementation, and absence of proper regulation to control unsustainable state spending.

According to Mensah and Castro (2004),²⁸⁹ sustainability is a dynamic concept rather than a constant state, it requires policy makers to be flexible and ready to adapt their approaches to changes in human demands, environmental changes, and technological advances. In other words, actions that improve sustainability today, either in perception or in reality, might be considered harmful in future.

In this regard, although the Omani government has been executing a series of 5-year socioeconomic development plans and Vision 2020 over the past 40 years, it has not successfully achieved its goals in relation to energy sustainability. Some of the issues are related to the fluctuations of the international oil prices, whereas other problems have resulted from setting overly ambitious targets in Vision 2020. For example, during the oil price boom, most of the GCC countries, including Oman, increased their investment expenditures and subsidy spending but when the oil price fell, the countries were not prepared. This decline in revenues makes it very difficult for the oil-exporting countries to create a balance between finishing the many ongoing projects that were initiated during the planning processes while maintaining the existing assets in a situation of limited financial resources. However, in 2015, as a result of the low oil price, the Omani government started implementing an austerity programme, stopping investments in many sectors of the economy as well as public service benefits in order to mitigate the urgent financial situation.²⁹⁰ Nonetheless, most of the austerity measures were reduced soon after oil prices started to recover. According to a Majlis Shura

²⁸⁸ Pohekar, S.D. and Ramachandran, M., 2004. Application of multi-criteria decision making to sustainable energy planning—a review. *Renewable and sustainable energy reviews*, 8(4), pp.365-381.

²⁸⁹ Mensah, A.M. and Castro, L.C., 2004. Sustainable resource use & sustainable development: a contradiction. *Center for Development Research, University of Bonn*.

²⁹⁰ CBO (2016) Annual report. Muscat: Central Bank of Oman.

member Tawfiq, if oil prices decline, Oman will be forced to use more financial control measures such as cuts in subsidies, public expenditure, and increases in non-oil taxes. However, such measures were not implemented, possibly because another oil boom was anticipated.²⁹¹

Flexible policy measures are essential for uncertainty of the fluctuation of oil prices. For example, during the implementation of the third Omani 5-year development plan, the government adapted rapid flexible policies to address the situation of the sudden fall of oil prices, which allowed Oman to overcome the shock of low oil prices without losing track of development and without reducing investments in social services. This flexible planning technique improved the soundness of socioeconomic development in an oil-exporting country. However, public expenditure was not sufficiently controlled during this plan and all other plans. This is attributed to two key reasons; the nature of policy implementation that has been executed in Oman depends heavily on its economic stability and the revenues from the export of oil and gas, which is subject to fluctuations, and the Omani policy planners had no control over the global political economy of oil and its consequent effects on oil revenues. Nevertheless, Omani policy planners did have the potential ability to limit the expansion of public expenditure and avoid the decline in the national economy savings. According to Leigh and Blakely, the issues occurring in planning policies were not due to insufficient technical skills and employees, but rather the type and extent of policy making.²⁹²

In fact, by analysing the planning policies, it can be observed that expanding the local economy requires energy policy to be defined in terms of a clear action plan with appropriate indicators and a dynamic monitoring and evaluation system. According to Vera and Langlois, achieving sustainability requires wise use of resources, proper economic incentives, technology, and unified strategic policy planning at the national level. In addition, it requires continuous monitoring of the effects of selected strategies and policies to ensure they are aligned with the core objectives.²⁹³

²⁹¹ Times of Oman. (2016). *Oman economy: Further oil price dip to force greater austerity, says IMF*. [online] Available at: <https://timesofoman.com/article/83922> [Accessed 20 Sep. 2018].

²⁹² Leigh, N.G. and Blakely, E.J., 2016. *Planning local economic development: Theory and practice*. SAGE publications.

²⁹³ Vera, I. and Langlois, L., 2007. Energy indicators for sustainable development. *Energy*, 32(6), pp.875-882

It is clear that without sustainable planning policies on expansion in different sectors of the economy and mitigating the risks associated with this expansion, such as oil price fluctuations and increasing local demand for energy, the oil-exporting countries could lose not only the revenues made from the exports but might also find that they are not capable of meeting the growing local energy demand.

3.3.2 Domestic energy demand

The second factor of energy sustainability is domestic energy demand. According to Hertog and Luciani (2009),²⁹⁴ achieving energy sustainability requires proper management of energy demand and understanding the measures that influence the performance of an energy system. Previous studies (Abdul Mujeebu and Alshamrani, 2016;²⁹⁵ Alnaser and Alnaser, 2011;²⁹⁶ Asif, 2016;²⁹⁷ Bayram and Mohsenian-Rad, 2016;²⁹⁸ Fattouh and El-Katiri, 2013;²⁹⁹ Kharrazi et al., 2015;³⁰⁰ Kinninmont, 2010;³⁰¹ Lilliestam and Patt, 2015;³⁰² Reiche, 2010;³⁰³ Strbac, 2008³⁰⁴) have recognised the main measures that influence significant increases in energy demand,

²⁹⁴ Hertog, S. and Luciani, G., 2009. Energy and sustainability policies in the GCC.

²⁹⁵ Abdul Mujeebu, M., & Alshamrani, O. S. (2016). Prospects of energy conservation and management in buildings - The Saudi Arabian scenario versus global trends. *Renewable and Sustainable Energy Reviews*. <https://doi.org/10.1016/j.rser.2015.12.327>

²⁹⁶ Alnaser, W. E., & Alnaser, N. W. (2011). The status of renewable energy in the GCC countries. *Renewable and Sustainable Energy Reviews*, 15(6), 3074–3098. <https://doi.org/10.1016/j.rser.2011.03.021>

²⁹⁷ Asif, M., & Muneer, T. (2007). Energy supply, its demand and security issues for developed and emerging economies. *Renewable and Sustainable Energy Reviews*, 11(7), 1388–1413. <https://doi.org/10.1016/j.rser.2005.12.004>

^{298,299} Bayram, İ. Ş., & Mohsenian-Rad, H. (2016). An overview of smart grids in the GCC region. In *Lecture Notes of the Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering, LNICST*. https://doi.org/10.1007/978-3-319-33681-7_25

²⁹⁹ Fattouh, B., & El-Katiri, L. (2013). Energy subsidies in the Middle East and North Africa. *Energy Strategy Reviews*, 2(1), 108–115. <https://doi.org/10.1016/j.esr.2012.11.004>

³⁰⁰ Kharrazi, A., Sato, M., Yarime, M., Nakayama, H., Yu, Y., & Kraines, S. (2015). Examining the resilience of national energy systems: Measurements of diversity in production-based and consumption-based electricity in the globalization of trade networks. *Energy Policy*, 87, 455–464. <https://doi.org/10.1016/j.enpol.2015.09.019>

³⁰¹ Kinninmont, J. (2010). *The GCC in 2020: Resources for the future*. Economist Intelligence Unit. https://doi.org/http://graphics.eiu.com/upload/eb/GCC_in_2020_Resources_WEB.pdf

³⁰² Lilliestam, J., & Patt, A. (2015). Barriers, risks and policies for renewables in the Gulf states. *Energies*, 8(8), 8263–8285. <https://doi.org/10.3390/en8088263>

³⁰³ Reiche, D. (2010). Energy Policies of Gulf Cooperation Council (GCC) countries-possibilities and limitations of ecological modernization in rentier states. *Energy Policy*, 38(5), 2395–2403. <https://doi.org/10.1016/j.enpol.2009.12.031>

³⁰⁴ Strbac, G. (2008). Demand side management: Benefits and challenges. *Energy Policy*, 36(12), 4419–4426. <https://doi.org/10.1016/j.enpol.2008.09.030>

including population growth, industrialisation, energy use per capita and behavioural change, low energy prices, and energy conservation and efficiency.

The Omani population is changing rapidly in terms of size and distribution. According to the World Bank, the population of Oman has doubled since 2010, to more than 4 million people.³⁰⁵ However, the main concern is not about the population size but rather the consumption per capita of natural resources, specifically oil and natural gas.

In conjunction with the Omani population increase, a significant increase in energy demand has occurred due to the expansion of different sectors of the economy, including industry, buildings, tourism, health, agriculture and fisheries, electricity generation, and transportation. Therefore, energy efficiency and conservation measures are needed to address the issue of matching energy supply with demand. According to the Scottish Environment Protection Agency, energy conservation and efficiency measures should be the highest energy policy priority because they can improve levels of pollution, decrease resource depletion, and enhance national energy sustainability.³⁰⁶

Many scholars (Abdul Mujeebu and Alshamrani, 2016;³⁰⁷ Al-Iriani, 2006;³⁰⁸ Alnaser and Alnaser, 2011;³⁰⁹ Posch, Brudermann, Braschel, and Gabriel, 2015³¹⁰) argue that globally, the industrial sector is demanding more energy than before because many of its industries are energy intensive by nature—eg, petroleum refining, petrochemicals, cement, metal and steel, aluminium smelting, building materials, and fertilizer production. This is especially the case in Oman, because almost all its industries are energy intensive. According to the annual report by the Authority for Electricity Regulation in Oman, one of the fastest growing energy consumption areas in Oman is the industrial sector.

³⁰⁵ The WB (2017) World bank indicators [online]. Available from: <http://data.worldbank.org/country/oman>

³⁰⁶ Sepa.org.uk. (2010). SEPA's Energy position statement. [online] Available at: https://www.sepa.org.uk/media/59374/sepa_energy_position_statement.pdf [Accessed 12 Sep. 2018].

³⁰⁷ Abdul Mujeebu, M., & Alshamrani, O. S. (2016). Prospects of energy conservation and management in buildings - The Saudi Arabian scenario versus global trends. *Renewable and Sustainable Energy Reviews*. <https://doi.org/10.1016/j.rser.2015.12.327>

³⁰⁸ Al-Iriani, M. A. (2006). Energy-GDP relationship revisited: An example from GCC countries using panel causality. *Energy Policy*. <https://doi.org/10.1016/j.enpol.2005.07.005>

³⁰⁹ Alnaser, W. E., & Alnaser, N. W. (2011). The status of renewable energy in the GCC countries. *Renewable and Sustainable Energy Reviews*, 15(6), 3074–3098. <https://doi.org/10.1016/j.rser.2011.03.021>

³¹⁰ Posch, A., Brudermann, T., Braschel, N., & Gabriel, M. (2015). Strategic energy management in energy-intensive enterprises: A quantitative analysis of relevant factors in the Austrian paper and pulp industry. *Journal of Cleaner Production*. <https://doi.org/10.1016/j.jclepro.2014.11.044>

Furthermore, energy prices are subsidised in all GCC countries, including Oman. These energy subsidies introduce inefficiencies in the market by encouraging the bad behaviour of careless energy consumption. The World Bank, International Monetary Fund, and United Nations Development Programme have concluded that subsidies have adverse effects and they can intensify pressure on a fiscal budget and crowd out public spending on important areas such as health, education, agriculture, fisheries, and resource allocation³¹¹. According to the Authority for Electricity Regulation, the electricity sector in Oman was subsidised by at least US\$1 billion in 2016, which is more than the previous year.³¹²

Other researchers (Abrahamse, Steg, Vlek, and Rothengatter, 2005;³¹³ Allcott, 2011;³¹⁴ Asif, 2016³¹⁵) stress that energy conservation measures can be important in reducing the energy demand of a country, because large quantities of energy are wasted, especially by public and private sector stakeholders in the electricity sector. However, conservation measures require effective policy interventions to control and incentivise the use of energy.³¹⁶

In relation to energy conservation measures, many academics (Asif, 2016;³¹⁷ Gillingham, Newell, and Palmer, 2006;³¹⁸ Li and Tao, 2017;³¹⁹ Pérez-Lombard, Ortiz, and Velázquez, 2013³²⁰) believe that energy efficiency is equally important to conservation in lowering the overall energy demand. According to Mahroum, energy efficiency measures can help in

³¹¹ Meltzer, J., Hultman, N.E. and Langley, C., 2014. Low-carbon energy transitions in Qatar and the Gulf Cooperation Council region.

³¹² AER (2016) Annual report. Muscat: The Authority for Electricity Regulation.

³¹³ Abrahamse, W., Steg, L., Vlek, C., & Rothengatter, T. (2005). A review of intervention studies aimed at household energy conservation. *Journal of Environmental Psychology*. <https://doi.org/10.1016/j.jenvp.2005.08.002>

³¹⁴ Allcott, H. (2011). Social norms and energy conservation. *Journal of Public Economics*. <https://doi.org/10.1016/j.jpubeco.2011.03.003>

³¹⁵ Asif, M. (2016). Growth and sustainability trends in the buildings sector in the GCC region with particular reference to the KSA and UAE. *Renewable and Sustainable Energy Reviews*. <https://doi.org/10.1016/j.rser.2015.05.042>

³¹⁶ Hertog, S. and Luciani, G., 2009. Energy and sustainability policies in the GCC.

³¹⁷ Asif, M. (2016). Growth and sustainability trends in the buildings sector in the GCC region with particular reference to the KSA and UAE. *Renewable and Sustainable Energy Reviews*. <https://doi.org/10.1016/j.rser.2015.05.042>

³¹⁸ Gillingham, K., Newell, R., & Palmer, K. (2006). Energy Efficiency Policies: A Retrospective Examination. *Annual Review of Environment and Resources*, 31(1), 161–192. <https://doi.org/10.1146/annurev.energy.31.020105.100157>

³¹⁹ Li, M. J., & Tao, W. Q. (2017). Review of methodologies and policies for evaluation of energy efficiency in high energy-consuming industry. *Applied Energy*. <https://doi.org/10.1016/j.apenergy.2016.11.039>

³²⁰ Pérez-Lombard, L., Ortiz, J., & Velázquez, D. (2013). Revisiting energy efficiency fundamentals. *Energy Efficiency*. <https://doi.org/10.1007/s12053-012-9180-8>

decreasing energy consumption and water consumption by 30% and reduce costs of consumer's energy bills by 50–70%.³²¹ However, the energy efficiency measures are not applied well in most GCC countries, especially in buildings. Energy efficiency in buildings is poor partly because they were poorly designed and constructed under the impression of the unlimited availability of subsidised energy resources. For example, most buildings in the GCC countries do not have proper insulation, efficient appliances, shading, or efficient windows.³²² Because it is now recognised that energy consumption is too high, energy efficiency measures are needed to address these problems not only in the building sector but also across all sectors of the economy.

This study argues that achieving energy sustainability cannot be analysed solely through the lens of energy demand, but with other energy sustainability factors in mind. It is crucial to restate that energy sustainability factors are interconnected. The performance of an energy system has an influence on energy demand, which in turn is a reflection of planning policies.

3.3.3 Energy diversification

The third energy sustainability factor is the diversification of energy mix within an energy system, so that a variety of energy resources is used (eg, solar, wind, biofuel, and geothermal). In most GCC countries, including Oman, there is poor energy diversification. This can be attributed to the fact that the abundance of hydrocarbons in oil-exporting countries has made governments in these regions extremely attached to oil income, which it uses to fund social and economic development in their countries, including education and health systems, so most attention and investments were directed to the oil and natural gas sector.^{323,324} However, oil-exporting countries face frequent and rapid fluctuation of oil revenue, which influences their economic performance and stability. According to Kandil and Nadwa, oil-exporting countries

³²¹ Mahroum, S., 2011. Construction Projects in the GCC: the opportunity and the missing link for a GCC-based eco-innovation. *Retrieved January, 10, p.2015.*

³²² Abu Bakar, N. N., Hassan, M. Y., Abdullah, H., Rahman, H. A., Abdullah, M. P., Hussin, F., & Bandi, M. (2015). Energy efficiency index as an indicator for measuring building energy performance: A review. *Renewable and Sustainable Energy Reviews*. Elsevier Ltd. <https://doi.org/10.1016/j.rser.2014.12.018>

³²³ Glada Lahn, P.S. and Preston, F., 2013. Saving oil and gas in the gulf. *The Royal Institute of International. Chatham House Report Affairs.*

³²⁴ Dreger, C. and Rahmani, T., 2016. The impact of oil revenues on the Iranian economy and the Gulf states. *OPEC Energy Review*, 40(1), pp.36-49.

are always driven by uncertainty about the future of oil prices and the fluctuation of the global market.³²⁵

Many scholars (Abdmouleh, Alammari, and Gastli, 2015;³²⁶ Dincer, 2000;³²⁷ Doukas, Patlitzianas, Kagiannas, and Psarras, 2006;³²⁸ Jacobsson and Johnson, 2000;³²⁹ Sims, 2004³³⁰) argue that governments in oil-exporting countries should reduce their dependence on oil and natural gas not only to sustain and stabilise their economic performance but also to improve their energy security through introducing renewables to their energy portfolio.

According to Emanuela and Abdelghani (2017),³³¹ the benefits of diversifying the hydrocarbons sector to include more sustainable energy resources such as solar and wind could potentially improve the overall development of the region, in terms of job creation, energy savings, energy security, industrialisation and energy access, and preventing greenhouse gas emissions. They note that the Middle East and North Africa regions have a strategic geographical location with climates offering the largest potential in the world for solar energy production. Switching to solar and wind resources in these regions would address climate change by decreasing CO₂ emissions markedly, because many countries in these regions are categorised as having some of the highest emissions in the world per capita. By diversifying to renewable energy resources in these regions, local oil and natural gas use can be decreased, allowing for more oil and natural gas resources to be used in more profitable ways, such as for export. Furthermore, the renewable energy sector can contribute to job creation and economic diversification. All GCC countries produce more than 45% of their total income from their oil and gas sector, but this sector only provides 1% of jobs.

³²⁵ Kandil, M., Nandwa, B., 2015. Oil dependency and exchange rate regimes in Arab oil economies: time to rethink the paradigm. *Applied Economics* 47, 5962–5995. doi:10.1080/00036846.2015.1061644

³²⁶ Abdmouleh, Z., Alammari, R. A. M., & Gastli, A. (2015). Recommendations on renewable energy policies for the GCC countries. *Renewable and Sustainable Energy Reviews*. <https://doi.org/10.1016/j.rser.2015.05.057>

³²⁷ Dincer, I. (2000). Renewable energy and sustainable development: a crucial review. *Renewable and Sustainable Energy Reviews*. [https://doi.org/10.1016/S1364-0321\(99\)00011-8](https://doi.org/10.1016/S1364-0321(99)00011-8)

³²⁸ Doukas, H., Patlitzianas, K. D., Kagiannas, A. G., & Psarras, J. (2006). Renewable energy sources and rationale use of energy development in the countries of GCC: Myth or reality? *Renewable Energy*, 31(6), 755–770. <https://doi.org/10.1016/j.renene.2005.05.010>

³²⁹ Jacobsson, S., & Johnson, A. (2000). The diffusion of renewable energy technology: An analytical framework and key issues for research. *Energy Policy*, 28(9), 625–640. [https://doi.org/10.1016/S0301-4215\(00\)00041-0](https://doi.org/10.1016/S0301-4215(00)00041-0)

³³⁰ Sims, R.E., 2004. Renewable energy: a response to climate change. *Solar energy*, 76(1-3), pp.9-17.

³³¹ Menichetti, E., El Gharras, A. and Karbuz, S., 2017. *Material Factors for the MENA Region: Energy Trends*. CIDOB

By contrast, domestic energy demand is currently increasing in all GCC countries because of expansion of industrial and construction sectors, subsidised energy prices, and increased water desalination. If energy consumption continues increasing at its current rate, this will lead to decreased export capacity because more resources will be directed toward meeting the growing domestic demand³³².

In this context of high domestic energy demand and heavy dependence on oil and natural gas, energy diversification is encouraged by many scholars (Bhutto, Bazmi, Zahedi, and Klemeš, 2014;³³³ Bujang, Bern, and Brumm, 2016;³³⁴ del Río and Burguillo, 2009;³³⁵ Ferroukhi, Ghazal-Aswad, Androulaki, Hawila, and Mezher, 2013;³³⁶ Galvani and Plourde, 2010;³³⁷ Owen, Inderwildi, and King, 2010³³⁸) to not only increase security of supply, economic stabilisation and diversification, and emissions reduction, but also to achieve better energy sustainability.

3.3.4 Environmental protection

The final factor of energy sustainability is that of environmental protection, which has been a popular topic in many academic research fields, including energy research. This interest is focused on the direct link between energy exploitation (eg, in production, distribution, transportation, and end use) and environmental deterioration.³³⁹ According to many scholars

³³² Lahn, G., Stevens, P. and Preston, F., 2013. *Saving oil and gas in the gulf*. Chatham House.

³³³ Bhutto, A. W., Bazmi, A. A., Zahedi, G., & Klemeš, J. J. (2014). A review of progress in renewable energy implementation in the Gulf Cooperation Council countries. In *Journal of Cleaner Production*. <https://doi.org/10.1016/j.jclepro.2013.12.073>

³³⁴ Bujang, A. S., Bern, C. J., & Brumm, T. J. (2016). Summary of energy demand and renewable energy policies in Malaysia. *Renewable and Sustainable Energy Reviews*. <https://doi.org/10.1016/j.rser.2015.09.047>

³³⁵ del Río, P., & Burguillo, M. (2009). An empirical analysis of the impact of renewable energy deployment on local sustainability. *Renewable and Sustainable Energy Reviews*. <https://doi.org/10.1016/j.rser.2008.08.001>

³³⁶ Ferroukhi, R., Ghazal-Aswad, N., Androulaki, S., Hawila, D., & Mezher, T. (2013). Renewable energy in the GCC: Status and challenges. *International Journal of Energy Sector Management*. <https://doi.org/10.1108/17506221311316498>

³³⁷ Galvani, V., & Plourde, A. (2010). Portfolio diversification in energy markets. *Energy Economics*, 32(2), 257–268. <https://doi.org/10.1016/j.eneco.2009.05.015>

³³⁸ Owen, N. A., Inderwildi, O. R., & King, D. A. (2010). The status of conventional world oil reserves-Hype or cause for concern? *Energy Policy*. <https://doi.org/10.1016/j.enpol.2010.02.026>

³³⁹ Sioshansi, F.P. ed., 2011. *Energy, sustainability and the environment: technology, incentives, behavior*. Elsevier.

(Ayres, 2008;³⁴⁰ Chappells and Shove, 2005;³⁴¹ Evans, Strežov, and Evans, 2009;³⁴² Omer, 2008;³⁴³ Varun, Prakash, and Bhat, 2009³⁴⁴), oil and natural gas consumption have had an adverse effect on the environment, contributing to the generation of gases such as CO₂, methane (CH₄), and nitrous oxide (N₂O), which are the main cause of climate change.³⁴⁵

Oil-exporting countries produce large amounts of greenhouse gas emissions from energy extraction processes such as the combustion of hydrocarbons for oil drilling activities, electricity generation, water desalination, and transportation. Although all GCC countries, including Oman, joined the Kyoto Protocol and the accession to UNFCCC in 2005 or 2006,³⁴⁶ their energy systems are operated under non-renewable energy resources (oil and natural gas), leading to more environmental damage and potential negative consequences of climate change.³⁴⁷ For example, the Omani average per capita carbon footprint is five times greater than the world average.³⁴⁸ This is attributed to the fact that the energy tariffs are cheap in Oman and there are no policies in place to regulate per capita CO₂ emissions.

The Saudi Minister of Petroleum and Mineral Resources stated that:³⁴⁹

“I firmly believe that when it comes to technologies aimed at mitigating climate change, the world has barely scratched the surface and the research, development, and innovation in this area need much greater attention than is

³⁴⁰ Ayres, R. U. (2008). Sustainability economics: Where do we stand? *Ecological Economics*. <https://doi.org/10.1016/j.ecolecon.2007.12.009>

³⁴¹ Chappells, H., & Shove, E. (2005). Debating the future of comfort: Environmental sustainability, energy consumption and the indoor environment. *Building Research and Information*. <https://doi.org/10.1080/0961321042000322762>

³⁴² Evans, A., Strežov, V. and Evans, T.J., 2009. Assessment of sustainability indicators for renewable energy technologies. *Renewable and sustainable energy reviews*, 13(5), pp.1082-1088

³⁴³ Omer, A. M. (2008). Energy, environment and sustainable development. *Renewable and Sustainable Energy Reviews*, 12(9), 2265–2300. <https://doi.org/10.1016/j.rser.2007.05.001>

³⁴⁴ Varun, Prakash, R., & Bhat, I. K. (2009). Energy, economics and environmental impacts of renewable energy systems. *Renewable and Sustainable Energy Reviews*. <https://doi.org/10.1016/j.rser.2009.05.007>

³⁴⁵ Solanki, P.S., Mallela, V.S. and Zhou, C., 2013. Estimation and diminution of CO₂ emissions by clean development mechanism option at power sector in Oman. *International Journal of Energy and environment*, 4(4), pp.641-652.

³⁴⁶ The Kyoto Protocol requires the GCC countries a commitment to reduce greenhouse gas emissions

³⁴⁷ Hertog, S. and Luciani, G., 2009. Energy and sustainability policies in the GCC.

³⁴⁸ Data.un.org. (2017). Oman greenhouse gas emissions. [online] Available at: <http://data.un.org/Search.aspx?q=Oman+carbon+> [Accessed 16 Sep. 2018].

³⁴⁹ Ali Naimi, Minister of Petroleum and Mineral Resources was interviewed by the Middle East Economic Survey on 17 November 2008.

presently the case. The list of what we can do includes, but is not limited to, multiple ways of greatly enhancing the efficiency of energy use in a variety of applications, cleaner and futuristic forms of conventional and unconventional fuels, and numerous ways of carbon capture and sequestration, besides many breakthrough technologies that are not even on the horizon today.”

Hertog and Luciani (2013)³⁵⁰ suggested that the adoption and development of renewable energy technologies in the GCC countries such as those of solar and wind could offer significant environmental and economic benefits. First, renewable technologies could improve public health, because renewables do not produce the pollutants that contribute to climate change, acid rain, smog, mercury poisoning, and respiratory diseases such as CO₂, sulphur dioxide (SO₂), mercury, nitrogen oxide (NO_x), or particulate matter into the water, air, or soil. Renewables are environmentally friendly, in that they do not harm the land as do the extraction processes of oil and gas. Furthermore, the use of renewables does not deplete them, meaning that they can be used for generations to preserve and protect the environment.

Economic benefits of renewable energies include an increase in employment opportunities. According to the US Energy and Employment Report (USEER) in 2017, job creation in the renewable energy sector exceeds that in the oil and gas sector by a margin of 5 to 1.³⁵¹ They also help to reduce oil dependency, which will increase long-term energy security, stabilise energy prices, and improve reliability of supply and resilience of the energy system. Further economic benefit from renewable energy sources is in terms of cost savings. Once the initial cost of construction and arrangement of a renewable source is covered, it can rapidly start to pay for itself because of low maintenance costs. Finally, revenues can be increased in oil-exporting countries by freeing up more oil and natural gas resources for export.

Although the Omani Ministry of Environmental and Climate Affairs has made many attempts to achieve environmental protection, no clear policies and strategies concentrating on climate

³⁵⁰ Hertog, S., & Luciani, G. (2013). Energy and sustainability policies in the Gulf states. *The Transformation of the Gulf: Politics, Economics and the Global Order*, (6), 236–257. <https://doi.org/10.4324/9780203813218>

³⁵¹ United States. Department of Energy, 2017. US energy and employment report.

issues exist (Steffen and Giacomo, 2009;³⁵² Hussein, 2011;³⁵³ A.H. Al-Badi et al., 2011;³⁵⁴ Ali et al., 2017³⁵⁵).

Environmental protection is an integral part of energy sustainability, and this is confirmed by numerous studies (Jay, 2010;³⁵⁶ Kalogirou, 2004;³⁵⁷ Panwar, Kaushik, & Kothari, 2011;³⁵⁸ Rees, 2003³⁵⁹). Based on the discussion and explanation of the importance of the suggested four factors of energy sustainability, this study develops a graphical conceptual framework for these factors, as can be seen in chapter one Figure 1-1.

3.4 Conclusion

This chapter developed a conceptual framework of four factors based on sustainable development theory, which influence energy sustainability policy: energy policies, domestic energy demand, diversification, and environmental protection. These were established from insights offered by energy sustainability and diversification theory. The chapter also illustrated why these factors affect energy sustainability.

Having created and presented the conceptual framework, the next chapter reviews the Omani energy sector and how this sector behaves towards energy sustainability.

³⁵² Hertog, S. and Luciani, G., 2009. Energy and sustainability policies in the GCC.

³⁵³ Kazem, H.A., 2011. Renewable energy in Oman: Status and future prospects. *Renewable and Sustainable Energy Reviews*, 15(8), pp.3465-3469.

³⁵⁴ Al-Badi, A.H., Malik, A. and Gastli, A., 2011. Sustainable energy usage in Oman—Opportunities and barriers. *Renewable and Sustainable Energy Reviews*, 15(8), pp.3780-3788.

³⁵⁵ Kazem, H.A., Al-Waeli, A.H., Chaichan, M.T., Al-Mamari, A.S. and Al-Kabi, A.H., 2017. Design, measurement and evaluation of photovoltaic pumping system for rural areas in Oman. *Environment, Development and Sustainability*, 19(3), pp.1041-1053.

³⁵⁶ Jay, S., 2010. Strategic environmental assessment for energy production. *Energy Policy*, 38(7), pp.3489-3497.

³⁵⁷ Kalogirou, S.A., 2004. Environmental benefits of domestic solar energy systems. *Energy conversion and management*, 45(18-19), pp.3075-3092.

³⁵⁸ Panwar, N.L., Kaushik, S.C. and Kothari, S., 2011. Role of renewable energy sources in environmental protection: a review. *Renewable and Sustainable Energy Reviews*, 15(3), pp.1513-1524.

³⁵⁹ Rees, W.E., 2003. Economic development and environmental protection: an ecological economics perspective. *Environmental monitoring and assessment*, 86(1-2), pp.29-45.

Chapter 4

Oman Energy Sector Review

4.1 Introduction

The current chapter provides an overview of the energy sector in Oman. The objective is to present a clear and comprehensive picture of the oil and gas sector and how this sector behaves towards energy sustainability. The chapter starts with the energy background and Vision 2020, then discusses primary energy supply and consumption. It discusses oil, natural gas, and electricity and water sectors in terms of regulation, supply and demand, and government investments in the sector. The renewable energy resources, in addition to electricity generation cost, are discussed.

4.2 Background

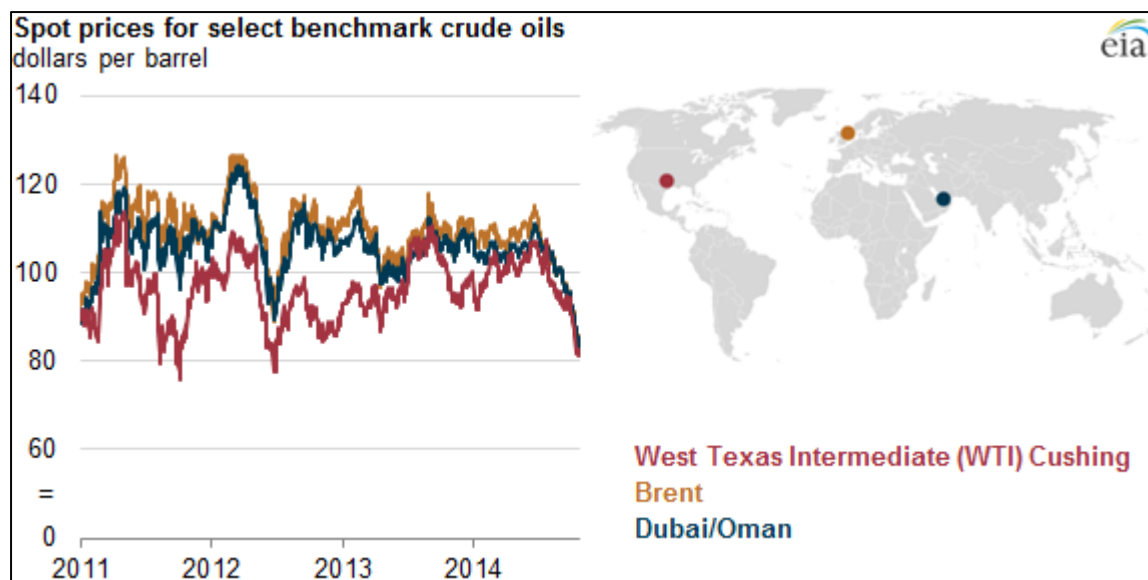
The economy of Oman is significantly dependent on fiscal revenues from oil and gas exports, unsustainable resources, accounting for 78.7 percent of total government revenues, 60 percent of total merchandise exports, and about 40 percent of GDP in year 2015. In addition, same year 2015, production of oil and gas increased by 5 percent comparing to year 2014, however the average price for Omani oil and gas declined significantly by 45 percent to US \$ 56 per barrel in 2015 from US \$ 103 per barrel in 2014 due to excessive supply in the international market.³⁶⁰

Oman's economy is extremely influenced by trends in the international oil market. In 2014 onwards, oil prices witnessed a sharp decline as outlined below.³⁶¹

³⁶⁰ CBO (2015) Annual report. Muscat: Central Bank of Oman.

³⁶¹ In 2008, oil prices reached a breaking record of US \$ 147 per barrel.

Figure 4- 1: Annually spot Oil Prices (US \$ per Barrel) by selected Benchmark (2011-2014)



Source: U.S. Energy Information Administration (2014)

According to Australian Institute of Petroleum (AIP), global crude oil prices can be influenced by some key factors, including:³⁶²

- Main supply interruption from natural catastrophes (hurricanes; Dennis, Rita & Katrina), civil unrest, war, and strikes (Iraq war, Libya, Arab spring and Middle East).
- Global financial crisis (occurred in 2008).
- Alternative fuel development (US produced Shale Gas).
- Rapidly increasing energy demand (economic growth in China and India).
- Global oversupply of crude oil and collapse of prices (occurred in 2014).

The sharp decline in oil prices that occurred in 2014 had a great impact on Oman's economy. The Central Bank of Oman reported a budget deficit of \$10 billion during 2015 (equivalent to 15 percent of nominal GDP) as against a surplus of \$4.1 billion budget during the previous year.³⁶³

³⁶² Australian Institute of Petroleum. (2017). Facts About the International Fuels Market and Prices | Australian Institute of Petroleum. [online] Available at: <https://www.aip.com.au/resources/facts-about-international-fuels-market-and-prices> [Accessed 5 Sep. 2018].

³⁶³ CBO (2015) Annual report. Muscat: Central Bank of Oman.

4.3 Energy Sector from the Vision 2020

Vision 2020 was first formulated when oil prices had been gradually declining for almost 15 years, which had direct effect on slowing down the overall economic development. Since then, oil prices have been witnessing some drastic fluctuations. Vision 2020 anticipated that the role of the government in the energy sector would shift from an assets owner to a regulator and market supporter. Vision 2020 aims at investing on private sector through promoting incentives for oil and gas exploration and extraction, restructuring the electricity sector and privatising governmental assets in the electricity power generation sector, enhancing gas exports and expanding domestic industrial areas through gas allocations.

In addition, one of the key focus of implementing Vision 2020 is to reduce the economic dependence on the share of oil GDP and increase the gas share of the GDP. It is anticipated that returns from oil extraction is gradually declining and the increase of gas extraction would, to a certain degree, mitigate the declining revenues from oil.³⁶⁴

4.4 Primary energy supply

Primary energy is an energy source found in nature that has not been subjected to any conversion or transformation process.³⁶⁵ According to International Energy Agency Statistics, in 2016, the total primary energy supply in Oman was 24,111 Ktoe,³⁶⁶ representing a threefold increase in energy supply since 2000, when it was 7,570 Ktoe.³⁶⁷ Even though the crude oil supply has not changed much, the share of gas has increased significantly, Figure 4-2. This increase was due mainly to electricity sector expansion in addition to the growth of intensive gas-based industries such as aluminium, cement, and steel plants.

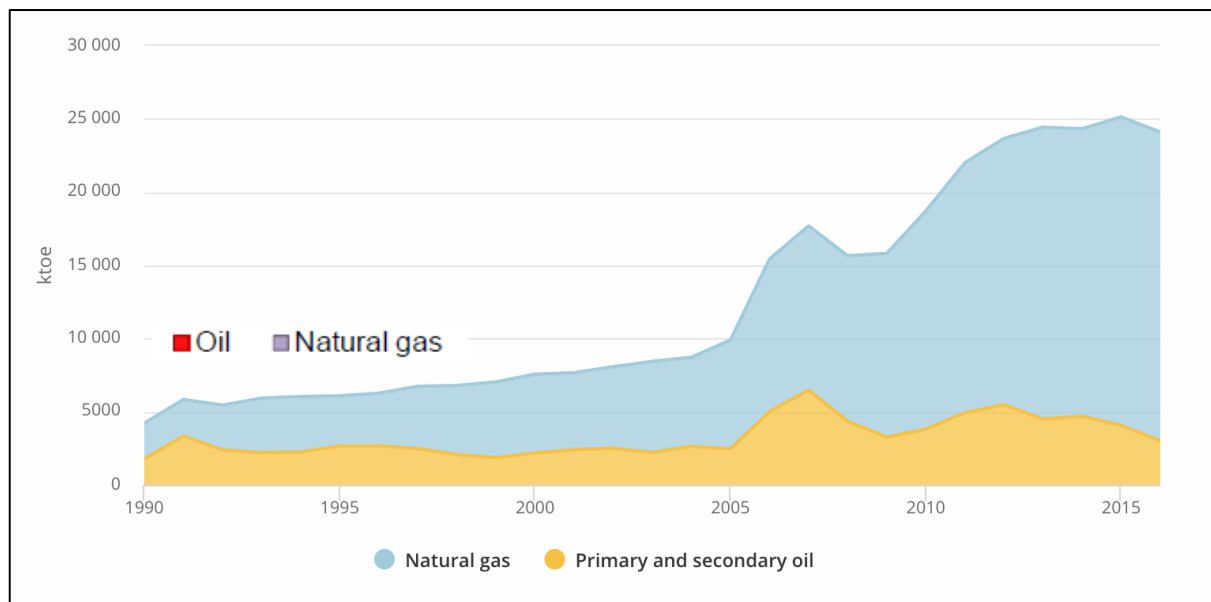
³⁶⁴ Government of the Sultanate of Oman Supreme Council for Planning Muscat (2017). A Plan Building on Achievements and Laying Foundations for the Future. Muscat: Supreme Council for Planning.

³⁶⁵ Øvergaard, S., 2008. Issue paper: Definition of primary and secondary energy. *Statistics Norway, Oslo*.

³⁶⁶ Ktoe refers to 1000 tons of oil equivalent.

³⁶⁷ International Energy Agency (IEA), 2018. Oman statistics.

Figure 4- 2: Total Primary Energy Supply (1990-2016)



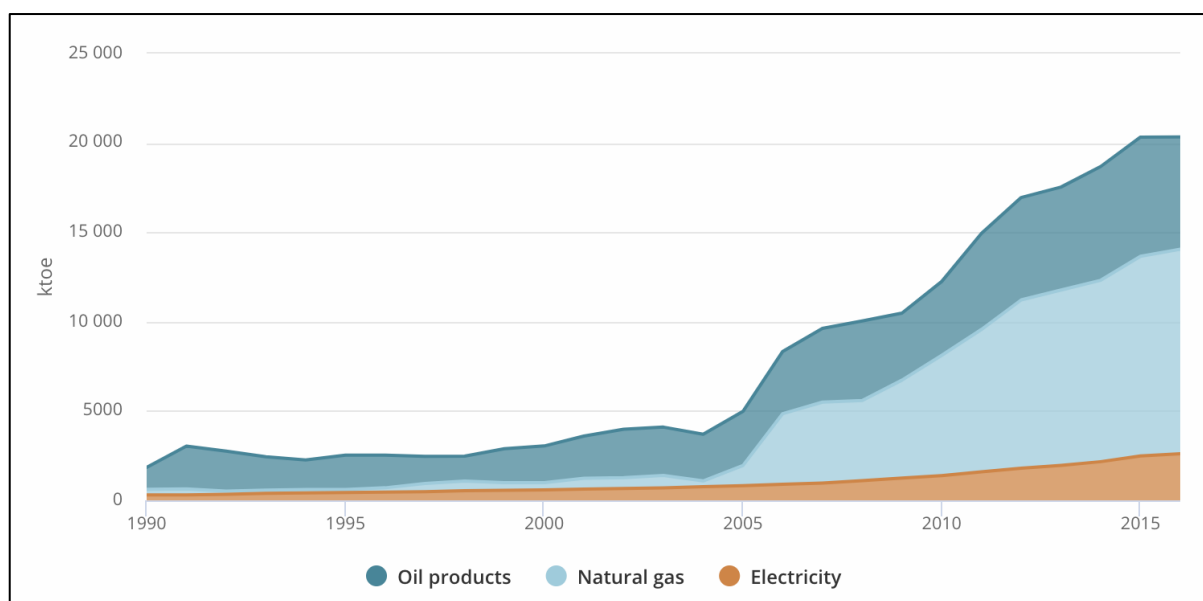
Source: International Energy Agency Energy Statistics, Oman (2018)

Primary energy consumption:

Oman's energy consumption has increased significantly from 3,042 Ktoe in 2000 to 20,335 Ktoe in 2016.³⁶⁸ Energy consumption has more than quadrupled due to population growth, rising per capita income, expansion in the general infrastructure, economic development, new industrial projects, and tourism. The industrial and transportation sectors are the highest energy consumers, followed by various other sectors such as residential and commercial and public services. Figure 4-3 depicts energy consumption by sector from 1990 to 2007.

³⁶⁸ International Energy Agency (IEA), 2011. Oman statistics.

Figure 4- 3: Total Final Consumption (1990-2016)



Source: The World Bank, Oman energy sector review (2018)

4.5 Oil Sector

4.5.1 Oil exploration

Oil was first discovered at Yibal in the northern part of Oman in 1962. More discoveries were made in 1964 at Fahud and Natih. The first commercial shipment of Omani oil was exported in 1967 through a 280 kilometre pipeline from the three fields (Yibal, Fahud, and Natih) to the oil-terminal at Mina Al-Fahal, in the capital of Oman, Muscat.³⁶⁹

The main player concerned with the extraction and exploration of fossil fuels is Petroleum Development Oman (PDO). It was first established in 1937 under the name of Petroleum Concession Oman. In 1960, Shell owned 85 percent of the company's shares and the remaining 15 percent was owned by Partex, which later renounced 10 percent of its shares to Compagnie Francaise de Petroles (CFP). In 1974, the Omani government acquired a 60 percent shareholding in PDO, the reminder being shared amongst Shell 34 percent, Total 4 percent, and Partex 2 percent.³⁷⁰

³⁶⁹ Al-Ismaily, H.A. and Probert, S.D., 1997. Energy overview for the sultanate of Oman. *Applied energy*, 57(4), pp.287-325.

³⁷⁰ PDO (2016) Annual report. Muscat: Petroleum Development Oman. [online] Available at: <http://www.pdo.co.om/en/news/publications/Publications%20Doc%20Library/Forms/DispForm.aspx?ID=154>

Amongst the sixteen oil producing companies in Oman,³⁷¹ PDO accounts for about 70 percent of the Omani oil production and nearly all of its natural gas supply.³⁷² In 2013, the average daily oil production accounted for 941,000 barrel per day, which has increased by 2 percent from the previous year.³⁷³ This increase is due to heavy investments in Enhanced Oil Recovery (EOR) techniques to maximize oil extraction.³⁷⁴

4.5.2 Regulation

The Ministry of Oil and Gas (MOG) acts as the regulator of the state's role in the energy sector, except for any environmental concerns falls under the Ministry of Environment and Climate Affairs (MECA). The main objectives of MOG is to provide a comprehensive policy framework and guideline for the energy sector, including developing legislation, monitoring exploration and production of oil and gas within the energy sector, preparing agreements with oil and gas companies, and selling crude oil and natural gas.³⁷⁵

The oil and gas law has positively fulfilled the state's objectives for a well-established and profitable oil sector. This flexible law allows international oil companies (IOCs) negotiate the exploration and production sharing agreements (EPSAs), resulting in attracting a number of foreign oil companies to involve in capital-intensive investments to exploit some of Oman's complex reserves. In addition, in 2013, the Ministry of Oil and Gas started implementing a modified policy for individual agreements with oil and gas companies to maximise the amount of profit, providing additional \$64 billion of hydrocarbons value and more than 30 thousand jobs for Omani within the energy sector through 2020.³⁷⁶

³⁷¹ Sixteen Crude oil production companies in Oman, namely: PDO, Petrogas, Occidental, Daleel Energy, PTTEP, DNO, BP Oman, CC Energy, Circle Oil, Odin Energy, PetroTell Oman, Masirah Oil, Oman Oil Company Exploration & Production, Frontier Resources Oman, Mol Oman, and Total Exploration & Production Oman Petroleum B.V.

³⁷² PDO (2016) Annual report. Muscat: Petroleum Development Oman. [online] Available at: <http://www.pdo.co.om/en/news/publications/Publications%20Doc%20Library/Forms/DispForm.aspx?ID=154>

³⁷³ NCSI (2014) Statistical yearbook. Muscat: National Centre for Statistics and Information.

³⁷⁴ Enhanced Oil Recovery (EOR) is the terminology that describes a series set of techniques used to increase the amount of crude oil that can be removed from the oil field. By adopting these techniques, it allows for more oil extraction, 30 to 60 percent and more in some cases.

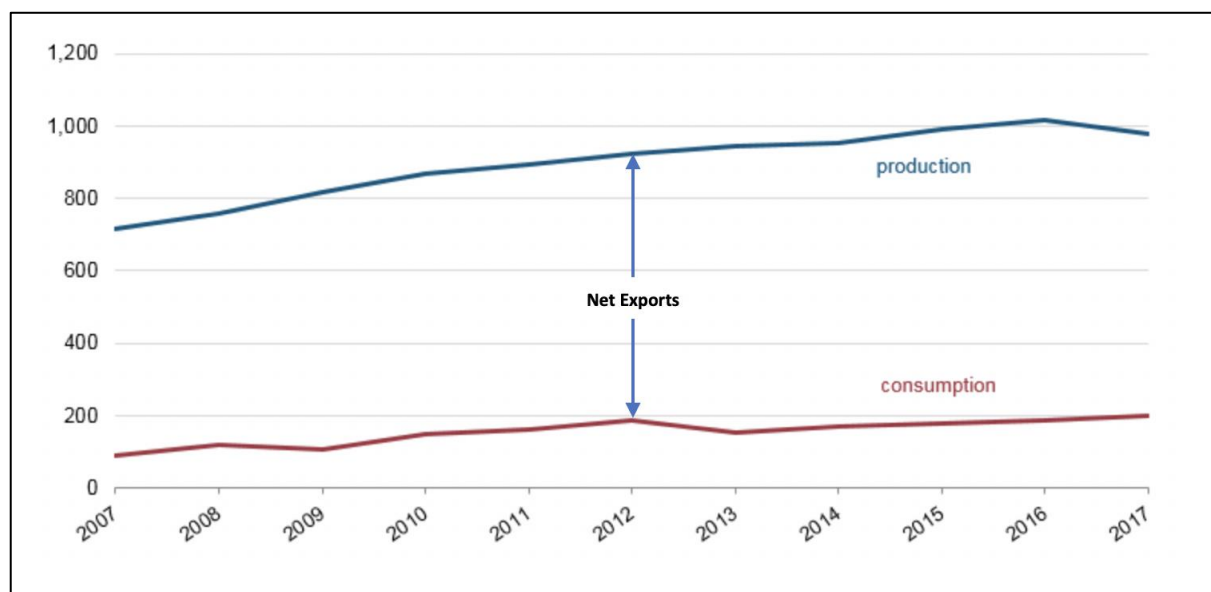
³⁷⁵ Ministry of Oil and Gas. (2016). Oman Ministry of Oil and Gas | Open Energy Information. [online] Available at: https://openei.org/wiki/Oman_Ministry_of_Oil_and_Gas [Accessed 6 Sep. 2018].

³⁷⁶ Oxford Business Group. (2016). The Report: Oman 2016. [online] Available at: <https://oxfordbusinessgroup.com/oman-2016> [Accessed 6 Sep. 2018].

4.5.3 Oil production, consumption, and export

Oil production has been fluctuating for the last two decades, with a slight increase starting from the end of 2007 onwards. The extensive exploration and extraction programmes started by the Ministry of Oil and Gas are essential to meeting the rising demand for oil products. As mentioned earlier, the adoption of EOR technology has allowed a rise in oil production in the last few years. The average daily oil production grew from 750,000 bpd to 918,000 bpd in 2017. Local consumption of oil has also increased from 98,000 bpd in 2011 to 197,000 bpd in 2017,³⁷⁷ due to government spending on general infrastructure projects as well as expansion across different sectors in the country. During the same period, oil exports also increased, from 738,000 bpd to 803,000 bpd. Figure 4-4 outlines Oman's oil production, local consumption, and exports.

Figure 4- 4: Oil production, local consumption and exports, thousand bpd, (2007-2017)



Source: International Energy Agency (IEA), 2018, Oman statistics.

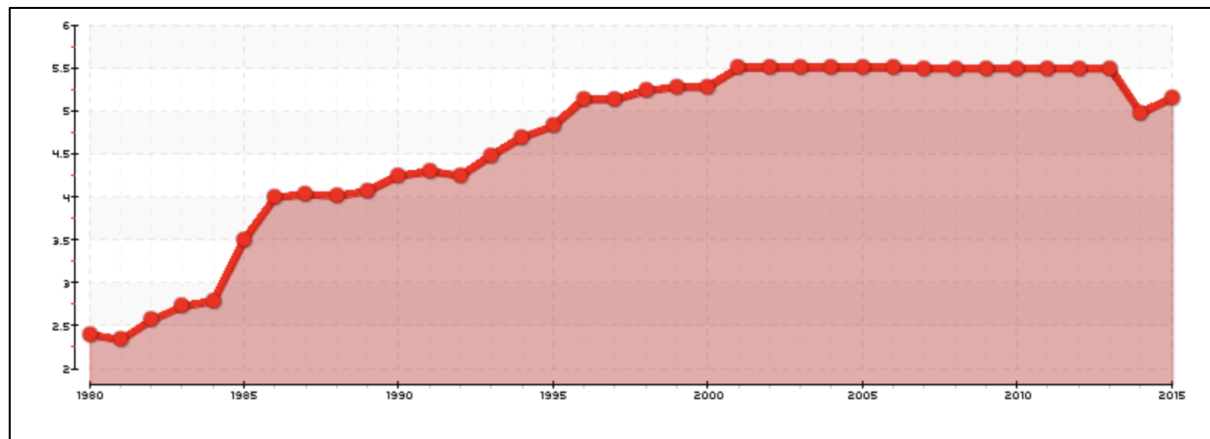
4.5.4 Oil reserves

At the end of 2015, Oman's proven crude oil reserves were accounted for 5 billion barrels, given that fact that this amount of oil reserves is extremely low comparing to some of Oman's

³⁷⁷International Energy Agency (IEA), 2018. Oman statistics.

oil exporting neighbours. In addition, the number of oil proven reserves has not increased since 1995.³⁷⁸ This means that oil is anticipated to last for less than two decades based on the current rate of production. Figure 4-5 presents the crude oil reserves from 1980 to 2015.

Figure 4- 5: Oman Crude Oil Reserves From 2002-2013 (Billion Barrels)



Sources: International Energy Agency (IEA), 2018, Oman statistics

There might be slight differences on the numbers of the estimated crude oil reserves in the reports. For example, the annual report of Ministry of Oil and Gas reported that the proved crude oil is 5.3 billion barrels by the end of 2015.³⁷⁹ Although the annual report highlighted that there was an increase of 1.3 percent of total reserves of crude oil in comparison with the previous year, the fact is that oil reserves are gradually diminishing.

4.5.5 Oil Recovery

Unlike Oman's neighbouring countries, the process of extracting oil is very difficult and requires intensive capital, due to Oman's complex geology and the viscosity and heaviness of its oil resources. The World Bank energy sector review reported that the average drilling depth of the oil well in Oman is about 1,200 meters (up to 5,000 meters), which couples with extra cost of production.³⁸⁰ For example, the cost of producing oil in Oman is relatively costly, fluctuating between US \$6-8 per barrel, while the cost of oil production in neighbouring country, specifically Saudi Arabia, is comparatively very low, averaging less than US \$1.5 per

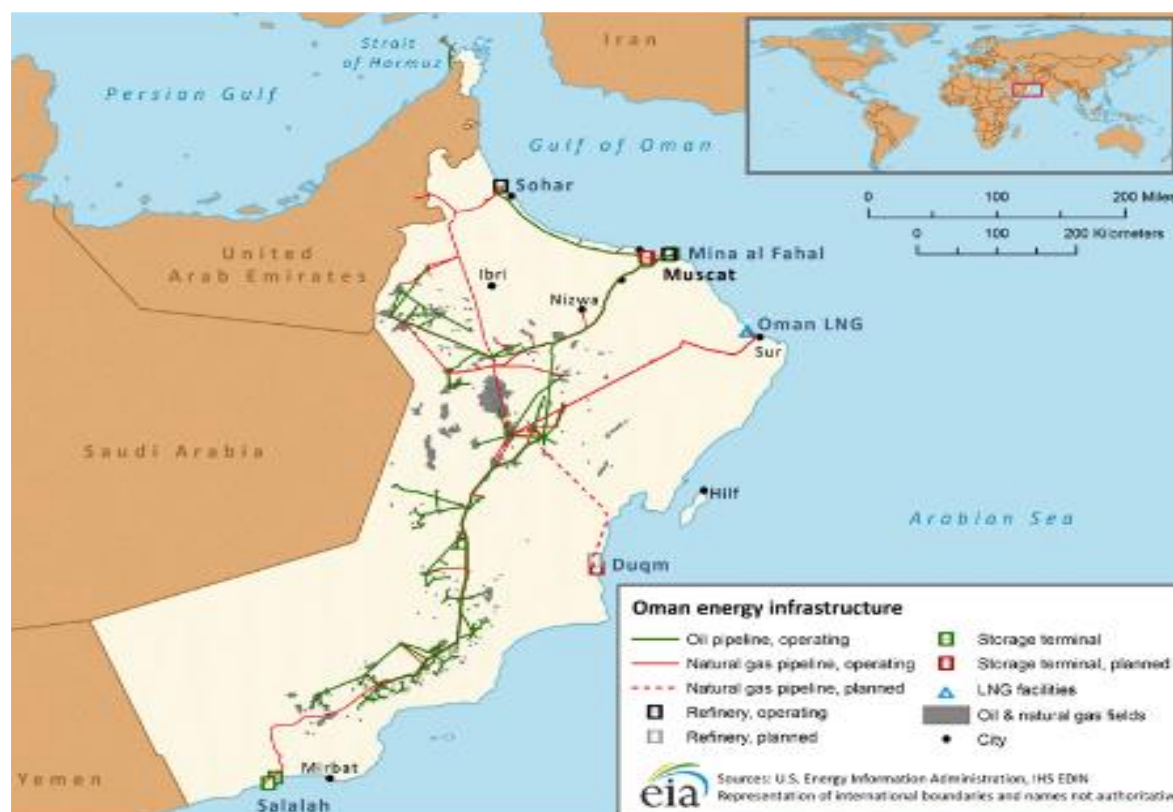
³⁷⁸International Energy Agency (IEA), 2018. Oman statistics.

³⁷⁹ MOG (2016) Annual report. Muscat: Ministry of Oil and Gas.

³⁸⁰ The WB (2017) World bank indicators [online]. Available from: <http://data.worldbank.org/country/oman>

barrel and the global average is around US \$5 per barrel.³⁸¹ In addition, oil fields are located in the very South or very North and pumped through pipes to Muscat, Mina Al-Fahal. Figure 4-6 shows over 2,600 kilometres of oil and gas pipeline infrastructure.

Figure 4- 6: Over 2,600 kilometres of oil and gas pipelines, 2016.



Source: U.S. Energy Administration Information, Oman energy infrastructure (2016)

The government of Oman invests heavily on oil exploration and drilling activities and these activities seems to be the highest in the region.³⁸² According to annual report of Ministry of Oil and Gas is that “one of the measures taken to face the energy sector is to intensify exploration, drilling and development in order to enhance supply quantities”.³⁸³ The oil reserves in general have been taking a decrease trend, due to the operational difficulties of the highly viscous oils and maturing wells. This has required the government to invest heavily in

³⁸¹ Stauffer, T., 1999. The economic cost of oil or gas production: a generalised methodology. *OPEC review*, 23(2), pp.173-195.

³⁸² Oxford Business Group. (2016). The Report: Oman 2016. [online] Available at: <https://oxfordbusinessgroup.com/oman-2016> [Accessed 6 Sep. 2018].

³⁸³ MOG (2014) Annual report. Muscat: Ministry of Oil and Gas.

adopting more technologies to recover more oil out of these aging wells, especially Enhanced Oil Recovery (EOR) techniques.³⁸⁴

In 2006, oil production started to increase due to the application of EOR techniques. A gradual increase was witnessed from 269 million barrels in 2006 to 358 million barrels in 2015.³⁸⁵ However, the overall oil production and reserves have been declining. Thus, the government introduced two policies to maintain or increase the level of oil production and to expand the life of oil fields. First, the government raised significantly its investment in the use of smart field and EOR technologies. For example, the government spent \$11.5 billion on drilling and enhanced oil recovery projects.³⁸⁶ The second policy, the government encouraged independent oil companies by granting them licenses based on “production sharing agreements”, without financial commitments required, in order to ease the processes and attract international investors. The contract terms have become more favourable in Oman than in any other countries in the region, some contracts allow significant equity stakes in certain oil projects.³⁸⁷

4.5.6 Smart-Field Management

Oman’s aging oilfields and complex geological oil and gas reserves have required complex and varied solutions to reverse the declining trend. Oman has thoroughly managed its natural resources through adopting new and cutting-edge technologies to maximize oil and gas production for the last decade. This has allowed Oman to become one of the pioneering leaders in using smart-field technologies in the world, expanding the life of Omani oil reservoirs.³⁸⁸

In addition, the adoption of smart-field management based on information technology has allowed more control and automation in difficult-to-recover hydrocarbons. For example, high sophisticated controlling and monitoring tools were applied in oil and gas wells in the central

³⁸⁴ Enhanced Oil Recovery (EOR) technique is the process of obtaining stuck oil not recovered from an oilfield through certain extraction processes

³⁸⁵ NCSI (2016) Statistical yearbook. Muscat: National Centre for Statistics and Information.

³⁸⁶ heoilandgasyear.com. (2015). THE OIL & GAS YEAR The Who’s Who of the Global Energy Industry. Oman 2015. [online] Available at: https://www.theoilandgasyear.com/content/uploads/2015/08/TOGY_OMAN_2015_Preview.pdf [Accessed 6 Sep. 2018].

³⁸⁷ MOG (2016) Annual report. Muscat: Ministry of Oil and Gas.

³⁸⁸ Energy Information Administration (US) and Government Publications Office eds., 2016. *International Energy Outlook 2016: With Projections to 2040*. Government Printing Office.

Fahud and Natih fields, which resulted in expanding field life, reducing gas flare, and enhancing communication between the production departments and engineering.³⁸⁹

4.5.7 Enhanced oil recovery (EOR) techniques and costs

Oman depends heavily on extraction technologies to be able to maintain or increase the level of oil and gas production. According to PDO, there are several EOR techniques that have been adopted in Oman such as steam injection, polymer, solar, and miscible techniques.³⁹⁰ Steam injection technique is used to inject steam into oil wells, which makes the oil less viscous to be extracted. Miscible injection is a process adopted to inject gas miscible into the oil wells to increase pressure in the reservoir and removes oil from water. Polymer technique is used to improve the mobility of oil reservoir to the surface.³⁹¹ Solar techniques is adopted to heat water and inject it into the well as a steam.³⁹² For example, PDO is the pioneering leader in using EOR techniques, with the Qarn Alam field (steam), Marmul field (polymer), Amal field (solar), and Harweel field (miscible).³⁹³ Other expected EOR projects are in the development process. One example is the Miraah project, which will be one of the largest project in the world using solar thermal to generate steam used in oil extraction, which is projected to save 5.6 trillion Btus per year of local gas.³⁹⁴

On the other hand, EOR techniques require a continues massive financial to keep these techniques run, which puts a significant financial load on PDO. According to the undersecretary of the ministry of oil and gas stated that “in comparison with primary oil

³⁸⁹ Arab Gulf States Institute in Washington. (2016). Cutting-Edge Technology Boosts Oman's Oil and Gas Production - Arab Gulf States Institute in Washington. [online] Available at: <http://www.agsiw.org/cutting-edge-technology-boosts-omans-oil-and-gas-production/> [Accessed 6 Sep. 2018].

³⁹⁰ Pdo.co.om. (2017). Enhance Oil Recovery (EOR). [online] Available at: <http://www.pdo.co.om/en/technical-expertise/enhanced-oil-recovery/Pages/default.aspx> [Accessed 6 Sep. 2018].

³⁹¹ Butler, R.M., 1991. *Thermal recovery of oil and bitumen* (Vol. 46). Englewood Cliffs, NJ: Prentice Hall.

³⁹² Solar EOR technique is the first to be used in the Middle East, accomplished by GlassPoint Solar company in 2012 and operated in the following year.

³⁹³ Petroleum Development Oman. (2015). Breaking new Ground in Oil Recovery. [online] Available at: http://www.pdo.co.om/en/news/publications/Publications%20Doc%20Library/_PublicationsFile_EOR%20Breaking%20New%20Ground%20In%20Oil%20Recovery2015.pdf [Accessed 6 Sep. 2018].

³⁹⁴ Glasspoint.com. (2017). Oman has pioneered Enhanced Oil Recovery in the Middle East. [online] Available at: <https://www.glasspoint.com/markets/oman/> [Accessed 6 Sep. 2018].

extraction, which sometimes costs only \$4 to \$5 per barrel, EOR techniques come at an expense of \$10 to \$12 per barrel”.³⁹⁵ Despite the high costs of EOR, the expenses and energy involved in lifting and transporting crude oil to the export terminal are significant. For instance, PDO has continuously required a significant amount of gas as a fuel for its own operation.³⁹⁶

4.5.8 Oil production and water management challenge

According to the ministry of oil and gas, water management has become a critical challenge in Oman, due to the increasing amount of water production associated with hydrocarbon production in oil fields.³⁹⁷ In 2016, for every barrel of extracted oil, 7 barrels of water were associated. This number has even increased lately to 8-9 barrels of water per barrel of oil as well as further water production is anticipated, resulting in more cost of extracting oil.³⁹⁸ Figure 4-7 presents water production and oil production.

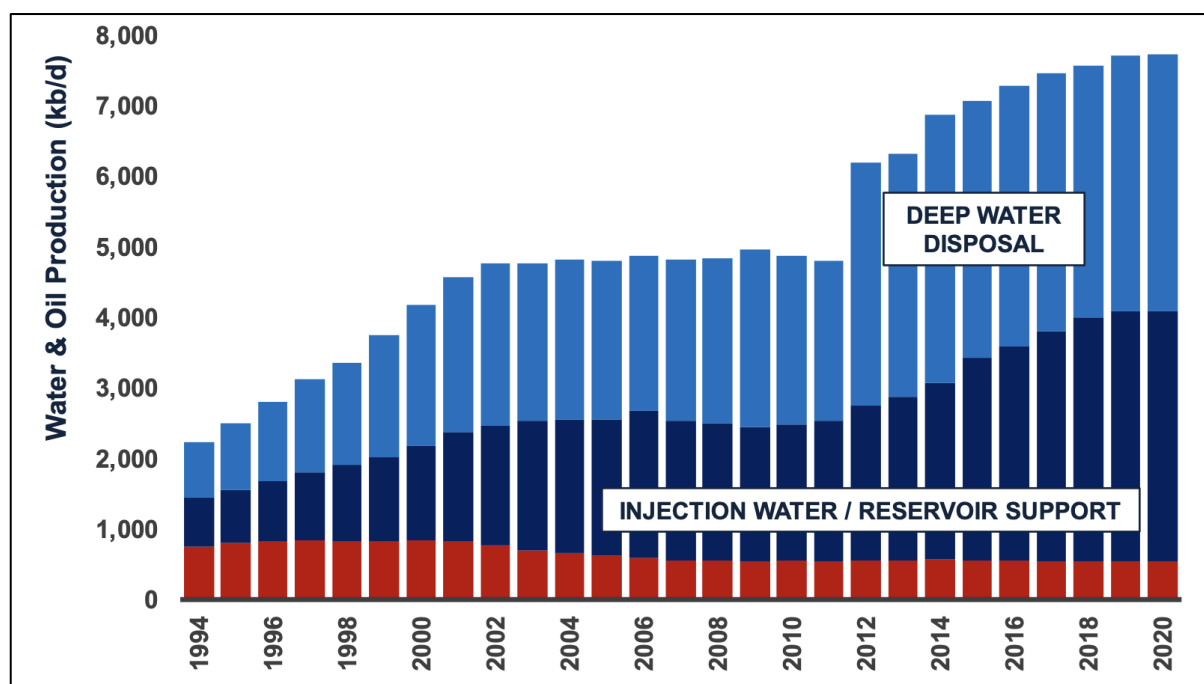
³⁹⁵ Atanasova, S. (2014). EOR costly for Oman oil production. [online] ArabianIndustry.com. Available at: <https://www.arabianindustry.com/oil-gas/oman/news/2014/sep/17/eor-costly-for-oman-oil-production-4818723/> [Accessed 6 Sep. 2018].

³⁹⁶ PDO (2016) Annual report. Muscat: Petroleum Development Oman. [online] Available at: <http://www.pdo.co.om/en/news/publications/Publications%20Doc%20Library/Forms/DispForm.aspx?ID=154>

³⁹⁷ MOG (2016) Annual report. Muscat: Ministry of Oil and Gas.

³⁹⁸ Yasmeen Al Lawati (2015) Water in the GCC towards efficient management, Produced Water Management & Treatment. [online]. Available from: <https://docplayer.net/46357313-Produced-water-management-treatment-dr-yasmeen-al-lawati-produced-water-management-sustainable-development-advisor-oman-water-society.html>.

Figure 4- 7: water vs. oil production thousand barrels per day (1994-2020)



Source: Yasmeen Al Lawati (2015)

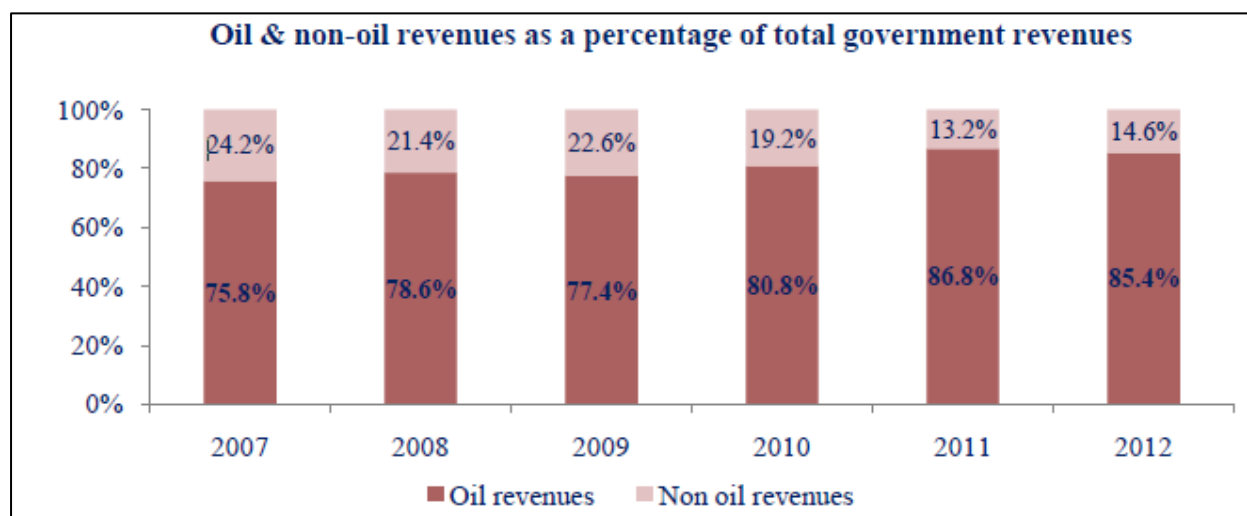
On the other hand, enhanced oil recovery wells require significant amount of water to generate steam necessary to heat and produce the heavy viscous oil. However, these EOR wells generate significant amount of very salty water (brine) at the surface, containing toxic and radioactive substances.³⁹⁹ Thus, this water must be treated before reinjecting it back into the wells. In other words, water production and water injection present a challenge in terms of technical or financial factor.

4.5.9 Oil as the main contributor to government revenues

Oman's revenue has maintained a steady growth for the last three decades. The revenue generated from exporting oil and gas is the primary source of the country. In 2007, the contribution of oil revenues accounted for 75.8 percent of total government revenues. In 2012, oil revenues increased to reach 85.4 percent of the total government revenues. Figure 4-8 shows the contribution of oil and non-oil revenues to total government returns.

³⁹⁹ About 45 percent of produced water is allocated for water injection, 1.5 percent is allocated for steam injection, and more than 50 percent is disposed back into deep geologic formations

Figure 4- 8: Total government revenues from year 2007-2012



Source: Al Maha Financial Research, Oman (2013)

In view of the heavy dependence on oil, any unexpected circumstances that affect the oil sector will impact significantly on Oman's revenues. This will not only cause a delay on the implementation of socio-economic development strategies, but it will also be a major obstacle to diversify within energy sector, since oil revenue is the main means of transforming this sector to more sustainability.⁴⁰⁰

4.5.10 Government investments in oil sector

As mentioned earlier, the Omani government developed a series of five-year action plans to achieve the principal goals of overall its development and to set out objectives for all its government sectors for the period 1976 to 1995. In the five-year action plan (1976-1980), the government allocated 247 million rials for the development of the energy sector, which represents a 21 percent of the total development investment for the country.⁴⁰¹ The second five-year action plan covered the period from 1981 to 1985. During this period, the investments gradually increased from 47 million rials to 72.3 million rials, about 14 percent of the total expenditure. At the same time, 76.4 million rials were spent on the oil resources development in the Petroleum Development Oman (PDO) activities, as part of the government's share. In

⁴⁰⁰ In 2014-2015, oil prices decreased dramatically, \$30 per a barrel of oil comparing to \$104 per barrel of oil the previous year, which caused the government a deficit budget of more than \$10 billion.

⁴⁰¹ Al-Ismaily, H.A. and Probert, S.D., 1997. Energy overview for the sultanate of Oman. *Applied energy*, 57(4), pp.287-325.

the third five-year action plan (1986-1990), the allocated money for development projects was shrunk due to the world oil shock in 1986. However, towards the end of year 1990, the allocated money for investments raised up, higher international oil prices, by 40 percent of the total annual development investments. The fourth five-year plan (1991-1995) witnessed an increase of the share of the oil resources development. This increase represented 36 percent of the total development investments, accounting for 156 million rials.

From 1996 onwards, the share of allocated money for investments on the oil development has been increasing significantly. Because not only prices of oil have been increasing, but also the difficulty of extracting oil is getting more expensive, due to the complexity of geology formation. For instant, in 2013 the government spent 753 million rials for the development of oil resources. This accounts for at least five times than the investments allocated in the early oil development in Oman.⁴⁰²

4.6 Natural Gas Sector

As mentioned in the previous section, Oman's geology is complex. Gas reserves are located deep in the geological structure, many even lower than the oil producing fields, at a depth of around 5,000 metres.⁴⁰³ Most of the gas production activities are located in the centre and west of Oman.⁴⁰⁴

Between year 1989 and 1991 large gas reserves were discovered in the central part of Oman, given the government an alternative energy resource to crude oil.⁴⁰⁵ In year 2000, the amount of gas produced was more than the domestic demand. Therefore, the Omani government took the opportunity of exporting the excess gas, which has resulted in the establishment of Oman Liquefied Natural Gas Company (OLNG).⁴⁰⁶

⁴⁰² MOG (2016) Annual report. Muscat: Ministry of Oil and Gas.

⁴⁰³ The WB (2017) World bank indicators [online]. Available from: <http://data.worldbank.org/country/oman>

⁴⁰⁴ Omani gas sector remained undeveloped for a while, due to complexity of gas reserves and financially not feasible.

⁴⁰⁵ Al-Ismaily, H.A. and Probert, S.D., 1997. Energy overview for the sultanate of Oman. *Applied energy*, 57(4), pp.287-325.

⁴⁰⁶ MOG (2012) Annual report. Muscat: Ministry of Oil and Gas.

Due to the expansion in the power and domestic industrial sectors has resulted in increasing local demand for gas. Therefore, the government increased the efforts in finding more gas through exploration programmes. In year 2006, the government agreed with British Gas (BG) for gas exploration and later that year agreed with British Petroleum (BP). In year 2012, there were five companies producing natural gas, namely; Petroleum Development Oman (PDO), DNO, Daleel Petroleum, Occidental Oman, and PTTEP.⁴⁰⁷

In year 2013, PDO has announced a discovery of large gas reserves in the central part of Oman, amounting to 2.9 trillion cubic feet (tcf) of gas and 115 million barrels of condensate, as well as, five new oil discoveries were made in 2012, accounting for 300 million barrels of stock tank oil initially in place (STOIIP) from two reservoirs.⁴⁰⁸

4.6.1 Gas production

Over the past decade, the gas sector has witnessed an increase of production, with minor fluctuations. In 2015, Oman produced 1.4 billion cubic meters of gas, a slight increase from 2014, due to the advancement and efficiency of gas extraction processes, which are seen in Figure 4-9.

⁴⁰⁷ MOG (2013) Annual report. Muscat: Ministry of Oil and Gas.

⁴⁰⁸ Energy-pedia news. (2013). Oman: PDO announces 2.9 tcf gas discovery at Mabrouk Deep. [online] Available at: <https://www.energy-pedia.com/news/oman/new-153711> [Accessed 6 Sep. 2018].

Figure 4- 9: Natural Gas Production (Billion Cubic Meters) from 2006 to 2015



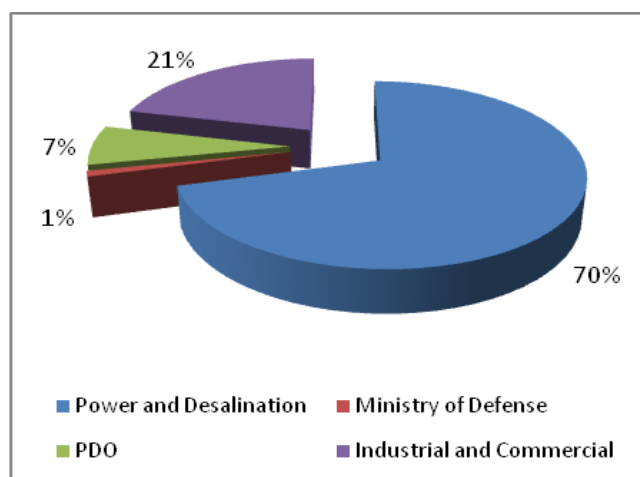
Source: National Center for Statistics and Information, Annual report 2016

However, Oman faces some issues concerning long term commitments to exporting natural gas, while importing a small amount of natural gas from Qatar during the hot summer to overcome the growing gap between production and consumption.⁴⁰⁹ In addition, domestic demand for gas has significantly increased, due to new power generation plants as well as industrial expansion, as mentioned above. According to the Ministry to Oil and Gas, 70 percent of total gas is allocated for power and desalination.⁴¹⁰ Figure 4-10 illustrates the share of gas by sector.

⁴⁰⁹ El-Katiri, L., 2013. Energy sustainability in the Gulf States: the why and the how. *Oxford Institute for Energy Studies*, http://www.oxfordenergy.org/wpcms/wp-content/uploads/2013/03/MEP_4.pdf, (accessed January 21, 2014).

⁴¹⁰ MOG (2016) Annual report. Muscat: Ministry of Oil and Gas.

Figure 4- 10: Gas Share by Sector



Source: Ministry of Oil and Gas, Oman (2016)

In 2015, Oman imported 5.4 million cubic meters of natural gas per day from Dolphin Energy company in order to meet increasing domestic demand.⁴¹¹ Thus, natural gas is increasingly becoming a critical energy source not only to reduce the gap between domestic energy supply and demand, but also to help the government pursue its economic diversification policy. In addition, the percentage growth rate of gas consumption is higher than production. In the near future, gas production will not efficiently fulfil export and domestic commitments as required unless new gas discoveries are made. Significant efforts need to be made by energy policy makers in order to ensure deficiencies of gas production will not impact negatively on the energy sector's development and its contribution to socio-economic development.

4.6.2 Natural gas reserves

According to BP Statistical Review of World Energy, Omani proven gas reserves amounted to slightly over 680 billion cubic meters in 2016, while the number of gas producing fields stood at 33.⁴¹² In year 2015, the total production of natural gas was 1,408,490 MNSCF of which 82 percent was non-associated reserve and the rest was associated gas.⁴¹³ Oman's natural gas reserves are very modest, in comparison to its neighbouring countries. Table 4-1 illustrates that Oman is one of the lowest estimated gas reserves amongst neighbouring countries.

⁴¹¹ CBO (2014) Annual report. Muscat: Central Bank of Oman.

⁴¹² Global, B.P., 2009. BP statistical review of world energy June 2009. *Relatório. Disponível em: <http://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html>*.

⁴¹³ NCSI (2016) Statistical yearbook. Muscat: National Centre for Statistics and Information.

Table 4- 1: Estimated Gas reserves in Iran and GCC, 2005 and 2014, in trillion cubic meters

Country	2005	2015
Iran	27.6	34
Qatar	25.6	24.5
Saudi Arabia	6.8	8.3
UAE	6.1	6.1
Kuwait	1.6	1.8
Oman	1.0	0.7
Bahrain	0.1	0.2

Source: British Petroleum (BP), Statistical Review 2016

4.6.3 Expected life of natural gas

As mentioned above, the total proven resources of natural gas accounted for 0.7 trillion cubic meters or 24.3 trillion cubic feet. With extraction rate of 1.4 billion cubic feet per year and if the rate of depletion remains constant thereafter, the recoverable reserves will be expected to deplete by year 2034, less than two decades. However, the annual production capacity rate of natural gas will probably be higher than the estimated above due to technology enhancement of gas extraction, which will possibly lead to shorten further the life of gas reserves.

4.7 Electricity and water sector

The accessibility of electricity is considered as a crucial factor for maintaining a modern way of life. Homes, refrigerators, schools, hospitals, and industries are all probably require electricity to keep them functioning. In some countries like Oman, the supply of fresh water requires a high demand of electricity for the process of sea water desalination.⁴¹⁴

4.7.1 The electricity and water sector market structure

The electricity system in Oman consists of three systems, which are not integrated electricity systems. The dominant system, also known as the Main Interconnected System (MIS),

⁴¹⁴ Al-Ismaily, H.A. and Probert, S.D., 1997. Energy overview for the sultanate of Oman. *Applied energy*, 57(4), pp.287-325.

generates 90 percent of the entire electricity required in the country and covers the northern part of Oman. The MIS encompasses fifteen power plants with a total of 28,000 GWh and 224 million cubic meter of desalinated water in 2015, comparing to 25,000 GWh and 184 million cubic meter of desalinated water in the previous year, with growth rate of 12.6 percent and 21.6 percent respectively.⁴¹⁵

The Rural Area Electricity Company (RAEC) covers the northern Musandam and the Central Al-Wusta regions. The Dhofar Power System (DPS) serves the south part of Oman, generating 3,100 GWh of installed electricity capacity and 22 million cubic meter in 2015, thus, an increase of 10 percent electricity generation and a decrease of 8 percent in water production.⁴¹⁶ The total installed electricity capacity of RAEC covers a much smaller scale accounts for 863 GWh and a desalination capacity about 3 million cubic meter in 2015, an increase of 14 percent and 17 percent respectively. Figure 4-11 presents the market structure of electricity and water sector.

⁴¹⁵ AER (2015) Annual report. Muscat: The Authority for Electricity Regulation.

⁴¹⁶ NCSI (2016) Statistical yearbook. Muscat: National Centre for Statistics and Information.

Figure 4- 11: Market structure of electricity and water sector, 2015



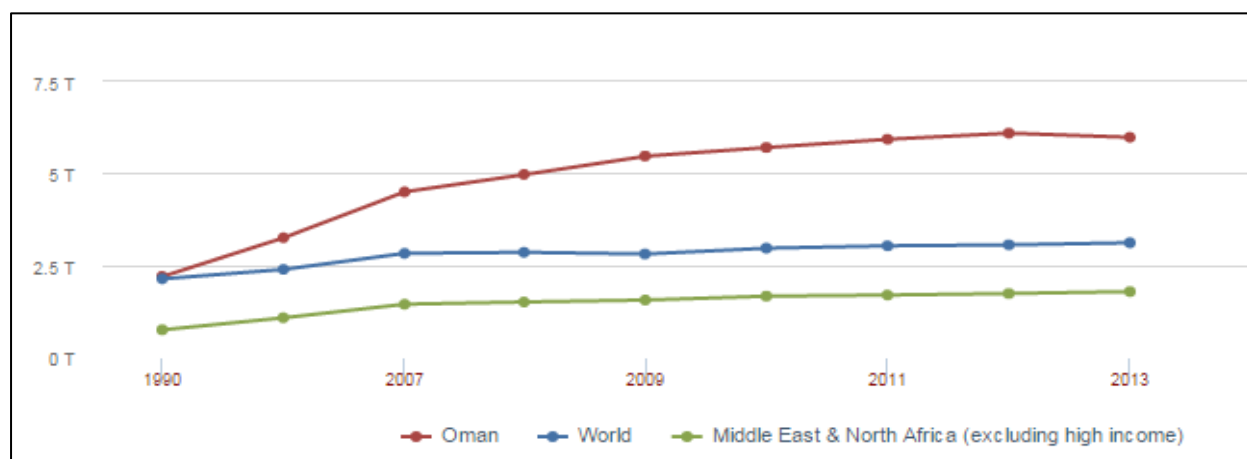
Source: Authority for Electricity Regulation, Annual report 2015

Both MIS and RAEC systems are under the responsibility of Oman Power and Water Procurement Company (OPWP), which is owned by the government. OPWP is the only buyer of all water and electricity generated by the MIS and DPS, usually purchases a 15- years contract. PDO, on the other hand, has its own electricity network infrastructure and power generating plants to meet its own needs of oil and gas operations.

4.7.2 Electricity production and consumption

The rapid national economic growth has been accompanied with a significant increase in electricity consumption. The total consumption of Oman electricity has increased from 720 GWh in 1980 to 28,000 GWh in 2015, representing an average annual growth rate of 11 percent.⁴¹⁷ The consumption of electricity per capita in Oman has significantly increased, from 2,000 kWh in 1990 to 6,000 kWh in 2013, representing an average growth rate of 5 percent. By comparison, the average electricity consumption in the Middle East and North Africa is 1,700 kWh per year, and 3,000 kWh per year is the world average. Figure 4-12 outlines the per capita electricity consumption in Oman, the Middle East and North Africa, and the World.

Figure 4- 12: Electricity power consumption (kWh per capita) from 1990 to 2013



Source: The World Bank (2017), electric power consumption

Thus, Oman's per capita electricity consumption is at least double the world average. The demand for electricity consumption has been steadily growing since 1980. During the year, the demand for electricity reaches a high peak in the hot summer due to the need for air conditioning, which accounts for 70 to 80 percent of total electricity consumption.⁴¹⁸ Another factor that contributes to the high electricity consumption is the government's subsidies. In 2015, the electricity sector subsidy amounted to \$ 1 billion.⁴¹⁹

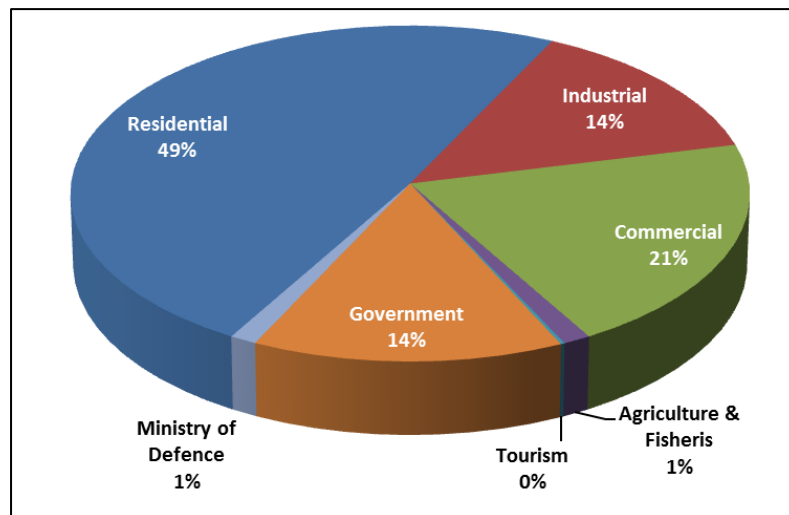
⁴¹⁷ The WB (2016) World bank indicators [online]. Available from: <http://data.worldbank.org/country/oman>

⁴¹⁸ TRC (2015) TRC MISSION, VISION AND OBJECTIVES [online]. Available from: <https://www.trc.gov.om/trcweb/about> (Accessed 15 January 2017).

⁴¹⁹ AER (2016) Annual report. Muscat: The Authority for Electricity Regulation.

The electricity consumption growth rate of 11 percent is higher than the national economic growth rate of 6 percent.⁴²⁰ The increase in electricity consumption has been attributed to the process of socio-economic development. The rapid growth of electricity consumption has been managed by adding new generation capacity. In 2015, the total power generation capacity was 28,000 GWh. Figure 4-13 illustrates the electricity supply by sector in 2015.

Figure 4- 13: Electricity supply by sector in 2015



Source: Authority for Electricity Regulation (2016)

From the pie chart, the residential sector has the highest share of electricity supply, accounting for 49 percent of total energy supply. The commercial sector is the second highest sector, representing 21 percent, followed by the industrial and governmental sectors, accounting for 14 percent each.

Meeting this increasing electricity demand by constructing new fossil fuel power plants is not sustainable in the long run and electricity policy need to integrate renewable energy resources to promote the diversification of electricity.

⁴²⁰ In 2015 the national economic growth rate recorded a sharp decline in the GDP due to the decrease in oil and gas prices, accounting for -14%.

4.7.3 Pricing structure and subsidy policy

The supply of electricity power for residents, wherever they are located in Oman, is regarded as an essential responsibility for the government. In order for the government to ensure that the electricity is available and affordable to people, it subsidises about 45 percent of total production and distribution costs of electricity used locally.⁴²¹ In addition, the government subsidises different sectors such as industrial, commercial, and agriculture in order to accelerate the development.

The Authority for Electricity Regulation (AER) regulates the pricing structure in electricity sector. The AER set the allowable revenue, known as economic cost of electricity, for OPWPC, OETC, and the fourteen distribution companies, which restricts the revenues they can gain.⁴²² The bulk electricity is purchased by the OPWPC from the electricity generation companies, as agreed in the Power Purchase Agreement (PPA). The Dhofar Power System (DPS) purchases electricity as agreed by the government. The OPWPC and OETC follow the Maximum Allowed Revenue formula (MAR) that controlled by the government to allow a slight percentage margin of power purchase cost to compensate for procurement associated risks.⁴²³

4.7.3.1 Electricity subsidy

Subsidy is defined as “the difference between the economic cost of Supply (including financing costs) and Permitted Tariff (and other) revenue”.⁴²⁴ The Article (18) of the sector law requires a mechanism, calculated by the AER, through which the Ministry of Finance subsidises the economic cost of electricity in order to compensate the four licensed distribution companies; MEDC, Majan, Mazoon, and MIS. Figure 4-14 depicts the total amount (Million OMR) subsidy by company in 2015.

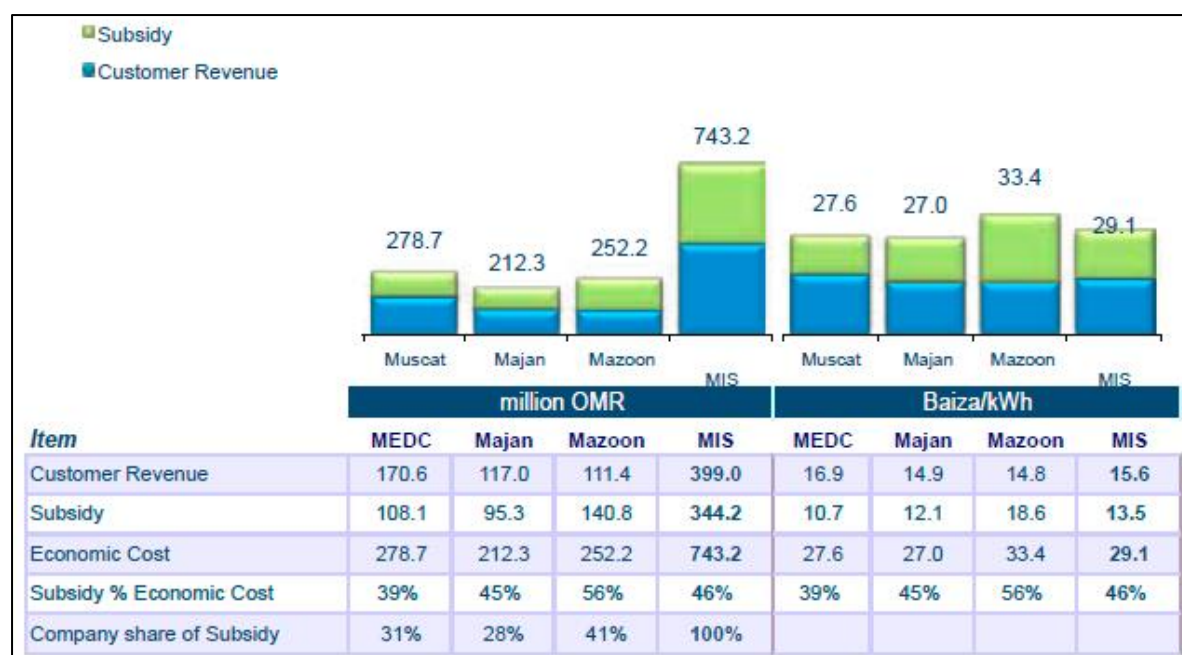
⁴²¹ AER (2016) Annual report. Muscat: The Authority for Electricity Regulation.

⁴²² AER controls the maximum allowed revenue (MAR) for OPWPC, OETC, and the distribution companies

⁴²³ AER (2015) Annual report. Muscat: The Authority for Electricity Regulation.

⁴²⁴ AER (2015) Annual report. Muscat: The Authority for Electricity Regulation.

Figure 4- 14: Total amount subsidy by company (Million OMR)



Source: The Authority for Electricity Regulation, annual report 2015

The MIS subsidy accounted for OMR 344.2 million of OMR 743.2 million of the total economic cost of supply, representing a subsidy of 46 percent. The remaining 54 percent of costs was regained through customer revenue.⁴²⁵ Mazoon, Majan, and MEDC calculated for 41 percent, 28 percent, and 31 percent, respectively, of the total MIS subsidy. In 2016, MIS, RAEC, and DPC calculated for OMR 384.8 million, OMR 72.6 million, and OMR 38.2 million of the total subsidy, which amounted totally to OMR 495.6 million.

4.7.3.2 Electricity Tariffs

The Council of Ministers approves all electricity supply tariffs or permitted tariffs to ensure that end-users are protected. Thus, end-user tariffs do not reflect the real costs assumed for the electricity generation, transmission, and distribution. Figure 4-15 illustrates the tariff structure.

⁴²⁵ There are three electricity networks in Oman; MIS, Rural system, and Dhofar Power system. This figure represents the MIS because it represents 90 percent of the total electricity system in Oman.

Figure 4- 15: Tariff Structure

Permitted Tariff Category	Tariff Structure				
Industrial	All regions except Dhofar			Dhofar region	
	September to April: 12 Baiza/kWh			August to March: 12 Baiza/kWh	
	May to August: 24 Baiza/kWh			April to July: 24 Baiza/kWh	
Commercial	Flat rate at 20 Baiza/kWh				
Ministry of Defence and the Sultan Special Forces	Flat rate at 20 Baiza/kWh				
Residential	0-3000 kWh	3001-5000 kWh	5001-7000 kWh	7001-10000 kWh	Above 10000 kWh
	10 Baiza/kWh	15 Baiza/kWh	20 Baiza/kWh	25 Baiza/kWh	30 Baiza/kWh
Government	0-3000 kWh	3001-5000 kWh	5001-7000 kWh	7001-10000 kWh	Above 10000 kWh
	10 Baiza/kWh	15 Baiza/kWh	20 Baiza/kWh	25 Baiza/kWh	30 Baiza/kWh
Agriculture & Fisheries	0-7000 kWh			7001 kWh & above	
	10 Baiza/kWh			20 Baiza/kWh	
Tourism	0-3000 kWh	3001-5000 kWh		5001-7000 kWh	Above 7000 kWh
	10 Baiza/kWh	15 Baiza/kWh		20 Baiza/kWh	20 Baiza/kWh

Source: The Authority for Electricity Regulation, annual report 2015

It can be noted from the tariff structure that this policy pricing is formulated to control the excessive use of electricity, specifically for the domestic sector. The lower the rate of electricity

consumption is, the lesser the rate charged per unit kWh per consumer.⁴²⁶ However, the cost of electricity per unit is very low, thus there is an essential need for subsidy requirement in order to compensate the distribution companies the difference between the economic cost of electricity and end-user revenue.

4.7.3.3 Water tariffs

On the other hand, the water bulk supply tariffs is approved by The AER and charged by PWP and RAEC to water departments. Figures 4-16 shows the PWP and RAEC water bulk supply tariffs.

Figure 4- 16: PWP and RAEC water bulk supply tariffs

PWP	Rate
Fixed charge for committed Water Desalination Capacity	OMR 0.377 per day per m3/day
Variable charge for Desalinated Water	OMR 0.089 per day per m3/day
PWP service charge (based on committed Water Desalination Capacity)	OMR 0.005 per day per m3/day
Variable charge for Distillate Water Supplied to MISC	OMR 0.3015 to 0.9618 per day per m3/day
RAEC Water Bulk Supply Tariff	OMR 1.340 per m3

Source: The Authority for Electricity Regulation, annual report 2015

The water sector in Oman is totally owned by the government, except for co-generation electricity plants, which does not fall under the same structure of the electricity sector in terms of privatisation in the market liberalisation.⁴²⁷ The water sector is highly subsidised by the government. However, the accurate level of performance in water sector in term of subsidy and economic costs of water is perhaps not clear, given the fact that the government is the sole player from water production, transmission to distribution. Therefore, end-user tariffs do not

⁴²⁶ CBO (2015) Annual report. Muscat: Central Bank of Oman.

⁴²⁷ Oman was the first country in the GCC and the region to deregulate and liberalise the electricity sector, in 2004, in order to attract international developers in invest and improve the efficiency of the sector.

reflect the real costs incurred for water services. In 2015, water supply accounted for 244 million cubic meter, accounting for an increase of 18 percent comparing to the previous year.⁴²⁸ This increasing demand of water has posed a greater challenge than, even, electricity sector. For example, in 2015 a severe water shortages were witnessed in 12 provinces, caused by some technical issues at the Sohar desalination plant, which impacted on more than 250 thousand people in May.⁴²⁹

4.7.3.4 Fuel Efficiency

The main feedstock for electricity generation and water production in the MIS is natural gas, provided by the Ministry of Oil and Gas. The efficiency of some power and water plants are very low, which can lead to consuming intensive gas to keep plants running. According to Oman Power and Procurement Company stated that “there is an essential need to build new plants not only to meet the increasing demand, but importantly to allow some of the older and more inefficient power stations to retire as they reach their end”.⁴³⁰ Therefore, the government introduced some new more efficient plants to operate in less intensively gas utilisation, but still the continues increasing demand for electricity and water will possibly remain a challenge for gas sustainability.

4.8 Renewable energy

The progress in renewable energy has been slow, due mainly to the high cost of renewable energy. Unlike neighbouring counties,⁴³¹ Oman depends totally on oil and gas to generate electricity. The reason for not pursuing renewable energies is that it is not feasible when oil

⁴²⁸ SAOC (2015) Annual report. Muscat: Oman Water and Procurement Co.

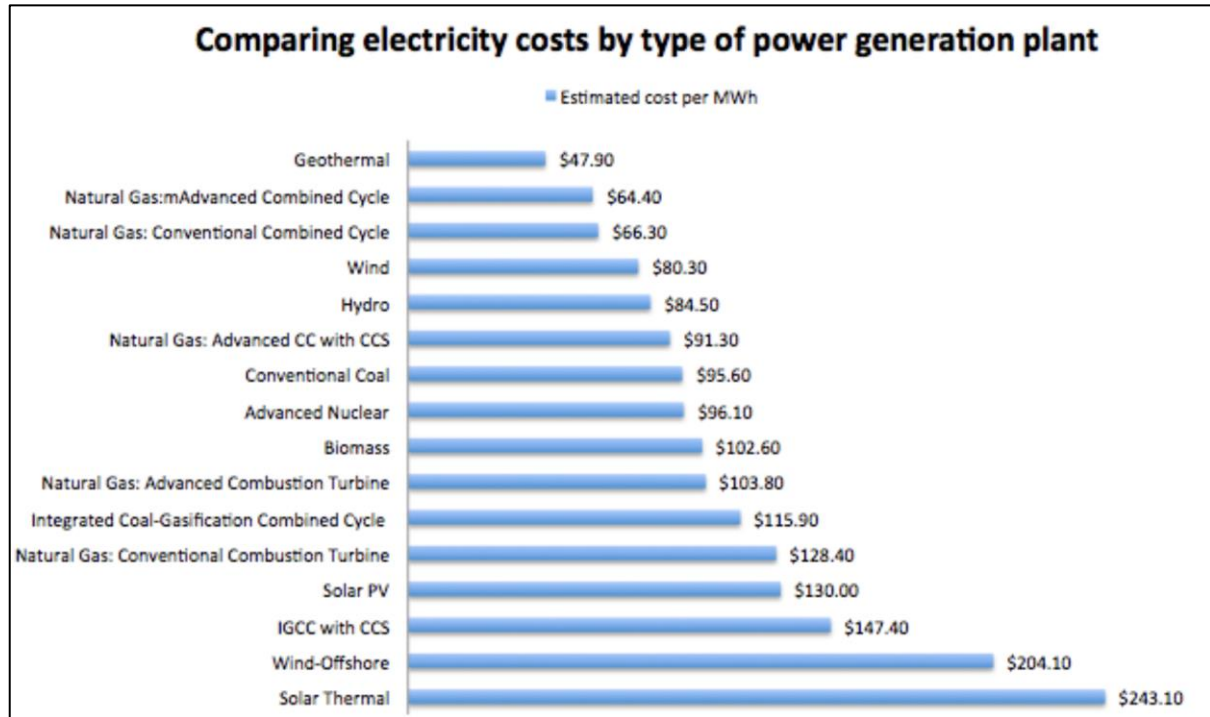
⁴²⁹ Oxford Business Group. (2016). The Report: Oman 2016. [online] Available at: <https://oxfordbusinessgroup.com/oman-2016> [Accessed 6 Sep. 2018].

⁴³⁰ SAOC (2015) Annual report. Muscat: Oman Water and Procurement Co.

⁴³¹ Some of the GCC countries have diversified their energy sources. The United Arab Emirates is running a renewable energy policy and in the process of constructing nuclear plants to generate electricity. Qatar’s energy strategy aims to generate 20 percent of its total energy from renewables by 2024.

and gas resources are relatively abundant at lower costs.⁴³² Figure 4-17 gives a comparison of electricity production costs through renewable and non-renewable energies.⁴³³

Figure 4- 17: A comparison between renewable and non-renewable energies, and electricity generation cost per MWh



Source: U.S. Energy Information Administration, (2016)

Thus, from a financial and economic point of view, renewable energies are not feasible. Strong political support is needed to initiate this technology since this type of energy is expected to become cheaper in the near future.

Despite the effort by the government to enhance the development of renewable energy resources, so far only a small amount of research has been conducted on renewable energy in Oman. However, at the national level, various government bodies, institutions, and individuals have conducted research focused mainly on wind, thermal, and solar energy. Most these studies have indicated that solar and wind energy resources have high potential in Oman. The country

⁴³² PDO and GlassPoint are working on a pilot project using solar thermal panels to generate steam that can help in extracting oil and gas by reinjecting steam into deep ground.

⁴³³ Authority for Electricity Regulation, Oman (2008). Study on Renewable Energy Resources, Oman Final Report. [online] muscat. Available at: http://regulationbodyofknowledge.org/wp-content/uploads/2013/09/AuthorityforElectricityRegulation_Oman_Study_on.pdf [Accessed 4 Sep. 2018].

is considered among the best areas of the world for solar energy and has the potential to meet all its domestic energy needs from solar energy.⁴³⁴ The following examples are some of the research studies that have been conducted on renewable energy:

- In 2013, a study was made by Yousef Al Hatmi and C.S. Tan to identify issues and challenges with renewable energy. The study highlighted certain issues surrounding renewable energy resources and why the deployment of this technology has been slow to take off.
- In 2011, a study was conducted by H. Kazem to investigate the status and future prospects of renewable energy in Oman. The study mainly focused on five renewable energy elements; solar energy, wind energy, hydro energy, biomass energy, and geothermal energy.⁴³⁵
- The Research Council (TRC), which is the only governmental funding agency for research in Oman, was established in 2005 and started to fund research projects actively in 2009. There are six thematic research sectors that have been identified for researchers to apply for funding. Renewable and alternative energies are categorized under the energy and industry sector. All the grants are directed at renewable energy such as solar, wind, and thermal energy.⁴³⁶ In addition, the Renewable & Sustainable Energies Research Group (RASERG) was established in 2003, at Sultan Qaboos University (SQU). The main objective of the group is to focus only on renewable energy aspects, for instance, solar, wind, and thermal energy.⁴³⁷
- The Authority for Electricity Regulation conducted a study on the renewable energy in 2008. The scope of the study focused mainly on the solar energy, wind energy, biogas, wave energy, and geothermal energy.⁴³⁸ The study found significant potential

⁴³⁴ Al Hatmi, Y. and Tan, C.S., 2013. Issues and challenges with renewable energy in Oman. *Gas (BCM)*, 4(9), pp.212-218.

⁴³⁵ Kazem, H.A. and Chaichan, M.T., 2012. Status and future prospects of renewable energy in Iraq. *Renewable and Sustainable Energy Reviews*, 16(8), pp.6007-6012.

⁴³⁶ TRC (2015) TRC MISSION, VISION AND OBJECTIVES [online]. Available from: <https://www.trc.gov.om/trcweb/about> (Accessed 15 January 2017).

⁴³⁷ Sultan Qaboos University (SQU). (2017). RASERG group. [online] Available at: <https://www.squ.edu.om/engineering/Research/Research-Groups/RASERG-group> [Accessed 6 Sep. 2018].

⁴³⁸ Authority for Electricity Regulation, Oman (2008). Study on Renewable Energy Resources, Oman Final Report. [online] muscat. Available at: http://regulationbodyofknowledge.org/wp-content/uploads/2013/09/AuthorityforElectricityRegulation_Oman_Study_on.pdf [Accessed 4 Sep. 2018].

renewable sources in solar and wind energy. Other sources were found to not be feasible for Oman.

- In early 2007, the government of Oman and Shell agreed to jointly review the actual performance of the oil and gas sector. Based on the data collected and analysed, the indicators showed a crucial need to find alternative energy resources. The only alternative resources suggested were solar power and wind power.⁴³⁹
- In 1997, a study was conducted by H. Al-Ismaily in the area of wind energy. The purpose of the study was to check the economic feasibility of wind power in different regions of Oman.⁴⁴⁰ It also included assessing wind behaviour for the entire country.
- In 1995, an experimental study was made by A. AL-Malkin, M. Al-Amri, and H AL-Jabri for the Ministry of Regional Municipality and Water Resources. The purpose of the experimental study was to assess the viability of using renewable energy in rural areas of Oman. Solar and wind energy were used in the desalination and pumping of ground water.⁴⁴¹

However, as mentioned earlier, Oman has been slow to deploy renewable energy resources because of the absence of policy instruments, besides the lack of finance to encourage renewable energy in Oman.

4.9 Conclusion

Oman is blessed with a plethora of natural resources, specifically oil and gas resources. Oil and gas resources have been the most important commodities for the country since 1967, producing 750,000 bpd in year 2007. This amount had increased to reach 918,000 bpd in year 2015; due to the adoption of EOR technology has allowed a rise in oil production in the last few years. The total amount of oil extracted is mostly exported; about 90 percent of oil is being exported and the rest is being consumed domestically. The proven crude oil reserves account for 5.5 billion barrels, and this number has not increased since 1995. Hence, unless new major

⁴³⁹ The WB (2017) World bank indicators [online]. Available from: <http://data.worldbank.org/country/oman>

⁴⁴⁰ Al-Ismaily, H.A. and Probert, S.D., 1996. Prospects for harnessing wind-power economically in the Sultanate of Oman. *Applied Energy*, 55(2), pp.85-130.

⁴⁴¹ Al Malki, A., Al Amri, M. and Al Jabri, H., 1998. Experimental study of using renewable energy in the rural areas of Oman. *Renewable Energy*, 14(1-4), pp.319-324.

discoveries are made, oil is projected to last for less than 20 years based on the current rate of extraction. Natural gas, on the other hand, is utilised mostly for electricity generation and for some intensive gas-based industries such as aluminium, cement, steel plants, and sea water desalination. In 2015, Oman produced 1.4 billion cubic metres of gas, a slight increase from 2014. However, Oman faces some issues concerning long term commitments to exporting natural gas, while importing a small amount of natural gas from Qatar during the hot summer to overcome the growing gap between production and consumption. With the current gas extraction and existing gas reserves, this resource is projected to be fully depleted by year 2034. However, the annual production capacity rate of natural gas will probably be higher than the estimated above due to technology enhancement of gas extraction, which will possibly lead to shorten further the natural gas sustainable period significantly. It might be wiser for the government to allocate money soon specifically for diversifying the source of energy supply and to find income other than fossil fuels before these resources totally exhausted. More serious and complex challenges are yet to be addressed as the energy policy has failed to introduce energy alternatives or encourage development in that direction.

Chapter 5

Research Methodology

5.1 Introduction

The proceeding chapter provides a brief overview of the research design and the methodology adopted in the present research. The objective is to describe the process by which the research questions are addressed. The chapter starts with the research approach used, then discusses its different philosophical assumptions, the data obtained in the current study, and secondary data gathered through previous research. It discusses the population of those involved in the Omani energy sector and clarifies how this population was sampled and examined through a number of different methods. The research limitations and drawbacks, in addition to certain associated ethical problems, are discussed.

5.2 Methodological approach

To date, various methods have been developed that have introduced philosophies founded on different competing assumptions, in terms of epistemology, the knowledge that we gain from what we know; and ontology, the nature of reality.⁴⁴² During the past 30 years, numerous studies have been conducted describing methodology, such as those by Miles and Huberman, 1984; Charles R., 1989; Joseph A., 2005; and Denzin and Lincoln, 2011. In fact, the literature in the field of research methodology is abundant, and to discuss the assumptions of each of the available theoretical approaches would require far beyond the capacity of a single thesis. In general, on the one hand, it is widely accepted that positivist philosophical paradigm strives to quantify structured data in parallel with the goal of testing hypotheses, in order to create objective and measurable laws. On the other hand, the interpretivist paradigm seeks to explore subjective means in order to produce a better understanding of the meaning or processes of a specific phenomenon.⁴⁴³ A number of studies, including a study by Saunders et al., 2009⁴⁴⁴ and Travers, 2001,⁴⁴⁵ have attempted to explain that positivism emphasises quantifiable observations, whereas the interpretivist approach is most likely suitable for qualitative

⁴⁴² Piergiorgio, C., 2003. Social research: Theory, methods and techniques.

⁴⁴³ Denzin, N.K. and Lincoln, Y.S. eds., 2011. *The SAGE handbook of qualitative research*. Sage.

⁴⁴⁴ Saunders, M., Lewis, P. and Thornhill, A., 2009. *Research methods for business students*. Pearson education.

⁴⁴⁵ Travers, M., 2001. *Qualitative research through case studies*. Sage.

investigations.⁴⁴⁶ It is true that such a clarification is not usually as well-defined as this in the literature, however it is normally considered to have a certain level of validity.

For the present research study, the methodological approach implemented is qualitative in nature, since the qualitative approach applies a greater depth to the investigation of situations or complex concerns when compared to the quantitative approach.⁴⁴⁷ Notably, however, there has been little detailed discussion regarding the energy diversification and the associated literature in the major oil exporting countries, including in the Middle Eastern countries, such as Oman. From this point of view, it may be more appropriate to implement an interpretivist stance.⁴⁴⁸ Furthermore, given the fact that there has been limited previous literature with regards to the application of such energy diversification in the Sultanate of Oman, and keeping in mind the vast debates on renewable energy agenda and the laws and regulations, it may be considered more suitable to adopt an inductive reasoning approach for the current research.⁴⁴⁹ Charmaz differentiates between an open-ended inductive reasoning and narrower deductive reasoning.⁴⁵⁰ She proposes that the former is generally concerned with the collection of data and then the creation of tentative theories, which are based on emerging forms. On the other hand, the latter attempts to start from theory and then move to data through the confirmation of hypotheses. In addition, John and Phil concluded that the researchers using the inductive reasoning method are most likely to deal with qualitative data and also to work within the non-positivist sphere.⁴⁵¹

It is crucially important, however, to bear in mind that the various philosophical approaches are not entirely exclusive of each other.⁴⁵² A number of scholars have highlighted that research rarely falls precisely into a single philosophical domain, and that in fact, research is usually a combination of positivism and interpretivism, which may also be driven from the stance of

⁴⁴⁶ Huberman, M. and Miles, M.B., 2002. *The qualitative researcher's companion*. Sage.

⁴⁴⁷ Maxwell, J.A., 2012. *Qualitative research design: An interactive approach* (Vol. 41). Sage publications.

⁴⁴⁸ Creswell, J.W. and Creswell, J.D., 2017. *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage publications.

⁴⁴⁹ Charmaz, K., 2006. *Constructing grounded theory: A practical guide through qualitative analysis*. Sage.

⁴⁵⁰ Ibid

⁴⁵¹ Gill, J. and Johnson, P., 2010. *Research methods for managers*. Sage.

⁴⁵² Maxwell, J.A., 2012. *Qualitative research design: An interactive approach* (Vol. 41). Sage publications.

realism.⁴⁵³ In addition, this view is supported by a variety of previous studies that have implied that, as it is widely accepted to use a combination of the qualitative and quantitative approaches in a single piece of research, the philosophical-driven arguments surrounding research methodology should therefore be prevented. However, it is of great importance to recognize how the implementation of a specific research approach could have impact on both the articulation of the research approach and the proper implementation of techniques for the sake of data collection and analysis. It has been suggested that a mixed research method of quantitative and qualitative types should be termed a 'pragmatic' philosophical paradigm. This paradigm permits both quantitative and qualitative methods to be implemented when addressing the research objectives with regards to the evaluation of both objective and subjective knowledge.⁴⁵⁴ Regardless of this, it may be the case that this does not help to solve the ontological questions of the nature of 'subjectively' and 'objectively', but rather it would be more reasonable to assume that the main concern of a pragmatic-oriented researcher is to provide a persuasive answer to the research questions that need to be addressed, using no single particular research method.⁴⁵⁵ While developing the methodology for the current study, a pragmatic stance with an interpretivist viewpoint has been identified as an appropriate diagram, in view of the qualitative approach.

Following a brief explanation of the different possible and previously suggested philosophical stances, it is of great importance to highlight the research strategy implemented with regards to the purpose of the enquiry. Pervez and Kjell define research strategy as a plan or framework for how the researcher approaches or addresses his/her research objectives, which is based on the priorities of the researcher.⁴⁵⁶ While Robson highlights a number of categories in which general research strategies occur, one of the most well-known categories is based on the general purpose of enquiry.⁴⁵⁷ There is agreement on the three most commonly used categories

⁴⁵³ Saunders, M., Lewis, P. and Thornhill, A., 2009. *Research methods for business students*. Pearson education.

⁴⁵⁴ Creswell, J.W. and Creswell, J.D., 2017. *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage publications.

⁴⁵⁵ Tashakkori, A. and Teddlie, C. eds., 2010. *Sage handbook of mixed methods in social & behavioral research*. Sage.

⁴⁵⁶ Ghauri, P.N. and Grønhaug, K., 2005. *Research methods in business studies: A practical guide*. Pearson Education.

⁴⁵⁷ Robson, C., 2002. *Real world research*. 2nd. Edition. Blackwell Publishing. Malden.

according to previous studies by Mohd Noor, 2008;⁴⁵⁸ Adams and Schvaneveldt, 1991;⁴⁵⁹ Denzin and Lincoln, 2011;⁴⁶⁰ and Zikmund and Babin, 2007.⁴⁶¹ They all describe the three different categories most often used for the purpose of research as exploratory, descriptive and explanatory. In view of this, Table 5-1 illustrates these three different types of research strategy as follows:

Table 5- 1: General characteristics of exploratory, descriptive and explanatory research strategies

Exploratory	Descriptive	Explanatory
<ul style="list-style-type: none"> · Usually for qualitative techniques · Practical for searching new ideas and exploring fairly unfamiliar issues or situations · Flexible in nature, without losing the purpose · Most likely using the ‘what is happening?’ in order to address the problem 	<ul style="list-style-type: none"> · Can be used for either qualitative or quantitative techniques · Most likely concerned with ‘Who? What? When? How?’ questions · Practical for finding general information or situations that are important for good explanatory research · Frequently uses in-depth description for a specific problem or situation 	<ul style="list-style-type: none"> · Mostly used for quantitative data · Seeks to answer ‘why?’ questions · Uses both exploratory and descriptive techniques. · Research published in journals are generally explanatory in nature · Creates causal linkages between events and variables

Source: Yin, R.K., (2017)

These research strategies could work separately to a certain extent, or in combination with each other. For the purpose of the current research study, a combination of the exploratory and descriptive strategies was adopted, as this combination is considered to be the most suitable for assessing the present research objectives. According to Yin, aspects of these techniques are not exclusive, and adopting an exploratory technique initially in research may later lean towards the descriptive technique.⁴⁶²

⁴⁵⁸ Noor, K.B.M., 2008. Case study: A strategic research methodology. *American journal of applied sciences*, 5(11), pp.1602-1604.

⁴⁵⁹ Adams, G.R. and Schvaneveldt, J.D., 1991. *Understanding research methods*. Addison-Wesley Longman Ltd.

⁴⁶⁰ Denzin, N.K. and Lincoln, Y.S. eds., 2011. *The SAGE handbook of qualitative research*. Sage.

⁴⁶¹ Babin, B.J. and Zikmund, W.G., 2015. *Essentials of marketing research*. Nelson Education.

⁴⁶² Yin, R.K., 2017. *Case study research and applications: Design and methods*. Sage publications.

5.3 Research design

As mentioned earlier in the current research study, a form of case study was undertaken for the project (the case of the Sultanate of Oman). It is suggested that this research methodology is appropriate for the exploration of research questions related to the ‘How?’, and the ‘What?’ questions, in addition to the ‘Why?’ questions.⁴⁶³ In previous research by Yin, who seems to lean towards adopting a positivist paradigm in research, he describes a case study as “An empirical inquiry that investigates a contemporary phenomenon within its real-life context when the boundaries between phenomenon and context are not clearly evident, and in which multiple sources of evidence are used”.⁴⁶⁴ In other words, the investigator has no ability to manipulate the relevant behaviour.⁴⁶⁵ Therefore, the case study method is suitable in particular when the researcher is dealing with complex situations, such as with regards to sensitive topics that are commonly unpublished or published with inaccurate data; and seeking to gain a rich understanding of the context of the research, in addition to the activities and processes that are being practised.⁴⁶⁶

It is true that all research techniques have advantages and disadvantages, as is the case for the case study technique. According to Robert, a lack of generalisation is one of the most common criticisms raised against case studies, which results in making the researchers of case studies often unable to generalise their findings.⁴⁶⁷ In addition, Table 5-2 describes the possible strengths and weaknesses of the case study technique.⁴⁶⁸

Table 5- 2: Strengths and weaknesses of the case study technique

Strengths	Weaknesses
<ul style="list-style-type: none">· They are based on reality· They can generate or test hypotheses	<ul style="list-style-type: none">· Findings might not be widely applicable (i.e. they cannot be generalised)· They can be time consuming to undertake in order to produce data

⁴⁶³ Yin, R.K., 2003. Case study research design and methods third edition. *Applied social research methods series*, 5.

⁴⁶⁴ Ibid

⁴⁶⁵ Ragin, C.C. and Becker, H.S. eds., 1992. *What is a case?: exploring the foundations of social inquiry*. Cambridge university press.

⁴⁶⁶ Cohen, L., Manion, L. and Morrison, K., 2000. Research Methods in Education, 5th edn (Abingdon: RoutledgeFalmer).

⁴⁶⁷ Scapens, R.W., 1990. Researching management accounting practice: the role of case study methods. *The British Accounting Review*, 22(3), pp.259-281.

⁴⁶⁸ Seale, C., Gobo, G., Gubrium, J.F. and Silverman, D. eds., 2004. *Qualitative research practice*. Sage.

<ul style="list-style-type: none"> · They provide a detailed description and understanding of a particular person, setting or event · They can be undertaken by a single researcher without needing a whole research group · They may offer some support to alternative interpretations 	<ul style="list-style-type: none"> · They are not easily open to cross-checking, thus may be selective, biased, personal and subjective.
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Source: Seale, C., Gobo, G., Gubrium, J.F. and Silverman, D. eds., (2004)

Despite the fact that the present study demonstrates an original contribution to the understanding of the role of energy diversification policy in national energy policy from the prospective of oil exporting countries, it is unlikely that the findings will be readily adopted for all countries around the world. According to Yin, despite the positive aspects of the case study approach, it may not produce an answer to the research question, and there is no reason to believe that most studies are representing statistical findings.⁴⁶⁹ However, there may be two justifications for theoretical generalisation whilst conducting such a case study. First of all, a number of theoretical propositions could be generated to understand how a diversified energy policy could be implemented in Oman. This means also that in further research, one may use such propositions and reflect them in other cases. Secondly, the findings of the current study may be applicable to those countries looking to sustain and diversify the natural energy resources that share a similar structure to those of renewable energy resources, as well as the oil exporting countries, especially those that rely heavily on fossil fuels.

As the present case study is explorative by nature, it is crucial to obtain well-informed and potentially key stakeholders in order to yield the best results. Indeed, obtaining sources of primary information is of great importance for any research project process.⁴⁷⁰ The author of the energy diversification policy has established contact with key stakeholders, such as (i.e. oil companies), This was possible as the author works at the Research Council (a government body), where the Research Council host/organise meetings between the three sectors. However, getting access to high-ranking officials and Omani individuals in particular, was a very difficult task. Not only because during Ramadhan, the working hours were short to keep everyone busy, but also due to the fact that the procedure of communication to obtain an appointment took a longer time than initially anticipated. Thus, new techniques of approaching individuals had to be adopted in order to get access to required information. One of the techniques required to shorten the procedure was to maintain either a direct communication from the chairman of the

⁴⁶⁹ Yin, R.K., 2017. *Case study research and applications: Design and methods*. Sage publications.

⁴⁷⁰ Ibid

Research Council to the head of the concerned organisation, or through official letters. Eventually, gaining access to high-profile officials was successful with regards to the government energy sector, which showed full support and willingness to provide the relevant data and information.

5.4 Data collection method

5.4.1 Secondary data (official documents)

A number of secondary data resources are needed in order to obtain a variety of information regarding aspects of Oman, specifically the energy sector. These data resources help improve the understanding of the energy sector, by clarifying its history, economy, population and background. Aspects such as these provide references backing the theoretical framework of this research study. Some examples of studies that have been conducted with regards to the renewable energy resources can be seen in the section 4.8.

The secondary resources that are of significant importance are those collected, documented and classified by the government, as well as data obtained from the archives of the governmental bodies associated with the energy sector in Oman. The sources of secondary information include annual reports, materials from conferences and workshops organized by these governmental bodies, as well as reports published by the international oil and gas companies, in which the Omani government plays a partner role. The secondary data resources were obtained from the following resources:

1. The annual statistical yearbook of population, economy, oil and gas, and electricity, which the National Centre for Statistics and Information publishes every year. These annual statistical reports provide data on the energy sector, including the extraction and export of oil and gas, economy indicators (such as gross domestic product and per capita income), size and distribution of the population, and electricity production and consumption. This information allows the researcher to assess the performance of the energy sector, in particular, allowing comparison with previous annual reports and the identification of energy trends and the possible projection of future situations.

2. Reports and statistical information provided by the Ministry of Oil and Gas. These reports provide information on oil and gas production, export and consumption, and energy prices. The main objectives of the Ministry of Oil and Gas include the development of energy policies, supervising the infrastructure of oil and gas projects, and planning the future of energy production and the development of technologies to investigate new resources. In addition, they describe the current status of the energy sector and energy projects, and updates/developments that are either in the implementation or operation phases. The data give general information regarding the development, progress and changes that have occurred or are in progress, in the energy sector of Oman. This allows the researcher not only to understand the whole energy system in Oman, but also to compare the behaviour of the energy sector over four decades.
3. Reports provided by the Authority for Electricity Regulation. The main competences of the AER include regulating the electricity and associated water sector. In 2008, the AER provided a report on promising renewable energy resources, such as solar and wind energy, in Oman. The current research benefited from the rich information on renewable energy resources, especially that regarding the solar, wind, wave and geothermal forms of energy, in addition to biogas. The report by the AER provides a comparison between renewable and non-renewable energy resources in terms of electricity generation and cost.
4. The seven-year statement published by the Oman Power and Water Procurement (years 2013-2019), which undertakes power generation planning and produces this statement. This statement includes the identification of novel methods of electricity generation that will be required for the future needs of Oman. In addition, reports are produced annually that provide figures about new energy projects and their capacities of electricity generation to meet the yearly increasing electricity demand.
5. Published papers by the SQU were a useful source of information on the renewable energy resources and their opportunities and challenges, as well as the energy efficiency and conservation. In addition, the SQU run initiative projects on renewable energy, specifically solar and wind projects. The Renewable & Sustainable Energies Research Group (RASERG)

was established in 2003 at SQU. The main objective of the group is to study renewable energy types, such as solar, wind and thermal energy.

6. The annual reports provided by the Central Bank of Oman, which provide an overview and outlook of the development of different sectors across Oman, including the economic growth, oil and gas sector, financial system, and the global economy outlook. The researcher benefited from a wide range of information regarding Omani oil and gas production and export prices, energy subsidies, in addition to other useful information concerning the major international oil and gas companies in Oman.
7. The annual reports produced by Petroleum Development Oman (PDO) provided a notable source of information relating to hydrocarbon production and the management of reservoirs, projects that enhance oil recovery, and environmental plans and programmes. Petroleum Development Oman (PDO) is the largest oil and gas producer in Oman, thus the researcher benefited not only from the publications and workshop materials, but also from the current initiative projects that host renewable energy resources, such as using solar power to generate steam for the purpose of extracting oil and gas.
8. Reports, strategies and visions provided by the Supreme Council of Planning, which include different sectors of Oman such as energy, economy, social and environment. One of the competences of the Supreme Council of Planning is to develop a comprehensive national strategy for long-term development in view of the natural and human resources available and the requirements for sustainable development in the country.

The reliable sources above were accessed through the websites, to seek data associated with the study topic. However, these references were of limited help in terms of accurate and in-depth information; they only provide general information and statistics about the energy sector of the country. This is also the case for governmental websites. Therefore, these websites were utilized for the collection of contextual information about the energy resources in Oman, the level of energy extraction and consumption, and the challenges these energy resources face, in addition to the significant efforts contributed by different governmental bodies to solve these challenges in the framework of the annual plans.

According to Rob and Nicholas, there may be a number of conceptual, methodological and economical reasons for collecting secondary data.⁴⁷¹ In the case of the conceptual prospective, there is no other data available in secondary sources. This then leads to the historical information, such as that regarding economy, energy or population, being only available from books and the annual report of the National Center for Statistics and Information. With regards to the methodological prospective, the researcher used secondary data resources to examine and explain the research outputs effectively, and to identify the answers to the research questions, particularly those related to the government efforts to regulate energy resources in the country during the last four decades through various plans and strategies. A number of the government efforts can be observed from the annual reports produced specifically for the energy sector. In addition, the annual reports provided by Petroleum Development Oman (PDO) and Shell Oman Marketing Company (SAOG) have benefited the researcher in the investigation and analysis of oil and gas production and consumption, and made it possible to predict the future of the energy situation in Oman. From the economic prospective, adopting secondary data resources could reduce the cost of collecting data. Travelling in Oman can consume time and effort. Thus, gathering secondary data resources results in saving more time and efforts.

However, using data from secondary sources could raise certain issues that it is important to be aware of during data collection. The researcher must be conscious of the validity and reliability of information, personal bias, and the availability of data. For example, information gathered from a census is more likely to be valid and reliable than that gathered from most personal diaries.⁴⁷² In addition, the reliability of published statistics might change over time. “It is not uncommon, for example, for the systems of collecting data to have changed over time but without any indication of this to the reader of published statistics. Geographical or administrative boundaries may be changed by government, or the basis for stratifying a sample may have altered”.⁴⁷³

⁴⁷¹ Kitchin, R. and Tate, N., 2013. *Conducting research in human geography: theory, methodology and practice*. Routledge.

⁴⁷² Smith, A.M., 2012. Research methodology: A step-by-step guide for beginners. *Nurse Education in Practice*, 12(3), p.e25.

⁴⁷³ Crawford, I.M., 1997. *Marketing research and information systems* (No. 4). Food & Agriculture Org.

5.4.2 Primary data (field work)

Interview is one of the most important methods of collection information from individuals. Through this method, the researcher can benefit from gathering valid and reliable information that seeks the answers to the specific research questions and objectives. According to Kumar an “interview is a commonly used method of collecting information from people. It is essentially a person-to-person interaction, either face to face or otherwise, between two or more individuals with a specific purpose in mind”.⁴⁷⁴ In other words, an interview includes an interviewer asking questions to respondents and recording their answers.⁴⁷⁵

One of the most crucial advantages of using interview is its adaptability, as the interviewer can keep track of ideas, examine motives and feelings, and investigate responses, which isn't possible using questionnaires. In addition, aspects other than the respondents answers can provide further information. These aspects may include the tone of voice, body language and facial expression, which may indicate reluctance or other emotions for example. Furthermore, interview responses can be explained further, clarified and developed between the interviewer and volunteer.⁴⁷⁶

According to Louise,⁴⁷⁷ there are a number of advantages of using the personal interview method, from which the researcher can benefit from during data collection:

1. It has the ability to overcome the short response rate of a questionnaire survey.
2. It is an appropriate method for the exploration of attitude, values, beliefs and motives.
3. It aids the evaluation of the validity of the respondent's answers, in that there is opportunity for detecting non-variable indicators, especially when discussing sensitive issues.
4. It ensures that all questions are answered by each respondent.

⁴⁷⁴ Smith, A.M., 2012. Research methodology: A step-by-step guide for beginners. *Nurse Education in Practice*, 12(3), p.e25.

⁴⁷⁵ Monette, D., Sullivan, T. and DeJong, C., 2013. *Applied social research: A tool for the human services*. Nelson Education.

⁴⁷⁶ Bell, J., 2014. *Doing Your Research Project: A guide for first-time researchers*. McGraw-Hill Education (UK).

⁴⁷⁷ Louise Barriball, K. and While, A., 1994. Collecting Data using a semi-structured interview: a discussion paper. *Journal of advanced nursing*, 19(2), pp.328-335.

5. It is confidential, and ensures that the respondent is not influenced by others while formulating a response.

The interview adopted in the present research is classified as semi-structured interview, with a certain extent of flexibility and specificity. This technique allows the researcher to ask a predetermined set of questions, and the interviews are usually scheduled for a convenient time and place.⁴⁷⁸ The list of questions adopted in the current research follows the same wording (all respondents were asked the same way) and order (questions were asked in the same order) across all interviews. The semi-structured interview instrument was selected, which is commonly implemented in qualitative kinds of research, due to its efficiency and flexibility in providing detailed information.⁴⁷⁹ One of the most important advantages of this technique is that it possesses the ability to perform as a complementary instrument, aiding the identification of the gaps in knowledge; and information that was not obtained from other research methods, such as secondary data resources.

All the questions in the interview were designed as open-ended questions, with the exception of one question. This allows respondents to express their ideas, opinions and recommendations freely in their own words. Therefore, the process of interviewing allows the researcher to analyse the effectiveness of the questions posed, and whether the responses are appropriate or sufficient (e.g. facial expression and tone of voice of interviewee). In addition, participants may use words, ideas or phrases in a specific way, and the researcher can investigate the significance of these aspects, which will likely add importance and depth to the information gathered.

⁴⁷⁸ Smith, A.M., 2012. Research methodology: A step-by-step guide for beginners. *Nurse Education in Practice*, 12(3), p.e25.

⁴⁷⁹ Longhurst, R., 2003. Semi-structured interviews and focus groups. *Key methods in geography*, pp.117-132.

5.4.3 The pilot study

The importance of pilot testing has been stressed by many scholars, including Kohlbacher,⁴⁸⁰ Yin,⁴⁸¹ Alen,⁴⁸² and Bill.⁴⁸³ Yin reported “Pilot studies help to test and refine one or more aspects of a final study—for example, its design, field work procedures, data collection instruments, or analysis plans”.⁴⁸⁴ Van and Hundley listed many reasons for conducting pilot studies such as developing and testing adequacy of research instruments, collecting preliminary data, developing a research question and research plan, and assessing the proposed data analysis techniques to uncover potential problems.⁴⁸⁵ Interview questions should be assessed and improved to obtain the relevant answers for the research.⁴⁸⁶ The pilot test is one of the most crucial elements in any study design because it helps the researcher determine whether there are limitations or any other errors or ambiguities that do not work for any reason. Furthermore, pilot testing allows the researcher to make essential revisions before implementation of the study.⁴⁸⁷ Therefore, researchers can eliminate any items that do not provide usable data, refine unclear questions, and ensure that the remaining questions are relevant and lead to appropriate answers to the research questions, and can also dig deep into the experiences or knowledge of the interviewees to gain useful data.

The comments provided were used to amend the questions and interview process accordingly:

- Rewriting or removal of questions with unclear wording.
- Sending the interview questions to the interviewees at least one week before the appointment, along with an explanatory letter, was important to ensure respondent participation.

⁴⁸⁰ Kohlbacher, F., 2006. The use of qualitative content analysis in case study research. In *Forum Qualitative Sozialforschung/Forum: Qualitative Social Research* (Vol. 7, No. 1, pp. 1-30). Institut für Qualitative Forschung.

⁴⁸¹ Yin, R.K., 2003. Case study research design and methods third edition. *Applied social research methods series*, 5.

⁴⁸² Bryman, A., 2016. *Social research methods*. Oxford university press.

⁴⁸³ Gillham, B., 2000. *Case study research methods*. Bloomsbury Publishing.

⁴⁸⁴ Yin, R.K., 2015. *Qualitative research from start to finish*. Guilford Publications.

⁴⁸⁵ Van Teijlingen, E. and Hundley, V., 2002. The importance of pilot studies. *Nursing standard*, 16(40).

⁴⁸⁶ O'donoghue, T., 2006. *Planning your qualitative research project: An introduction to interpretivist research in education*. Routledge.

⁴⁸⁷ Turner III, D.W., 2010. Qualitative interview design: A practical guide for novice investigators. *The qualitative report*, 15(3), pp.754-760.

- Voice recording—with approval from the interviewee—was crucial because it was difficult to take notes and interact with the interviewee at the same time.

5.4.4 Sampling design

Various steps were applied in formulating the survey used in the current study, and it consists of a number of qualitative techniques. The researcher developed the questions then they were reviewed by his supervisor, in order to confirm that the interview questions would cover the entire research issues. In addition to that, the researcher benefited from comments prepared by a senior government member, regarding the issue of energy conservation and energy subsidies in the current national energy policy of Oman.

One of the most important factors in obtaining data and information is adequate sampling design. This helps in the determination of the levels of reliability and accuracy of the survey findings. In addition, the survey findings not only depend on the processes the investigator uses to design his research sampling, but also the proper instruments that he applies for data collection.

According to Roger and Uma, sampling “is a process of selecting a sufficient number of the right elements from the population, so that a study of the sample and an understanding of its properties and characteristics make it possible for us to generalize such properties or characteristics to the population elements”.⁴⁸⁸

In this regard, a purposeful sampling strategy was employed. According to Martin, this is the most common technique used for qualitative studies, especially when there are few people involved in the area being investigated.⁴⁸⁹ In addition, it is essential to get information from a specific target, such as a specific type of respondent that is able to provide the investigator with the required information, either because this type of respondent is the only one that can supply the required information, or they fall under certain criteria set by the investigator. The

⁴⁸⁸ Sekaran, U., 2010. *Research Methods For Business: A Skill Building Approach* Singapore: John Willey dan Sonc.

⁴⁸⁹ Marshall, M.N., 1996. Sampling for qualitative research. *Family practice*, 13(6), pp.522-526.

investigator attempts to obtain information from energy policy-makers and government high-profile officials, which limits the sample size to those that have a direct influence on the national energy policy. Jankowicz stresses the proceeding idea that “the accuracy of your results will depend much more on the variety of different groups and subgroups in your population, and how much time and effort you can afford to spend rather than size”.⁴⁹⁰ The snowball sampling technique was also employed as a complementary sampling technique in the present study. This technique is a process of getting a sample by going to the first individual, who then identifies other individuals that may be key respondents. As it is not possible to recruit all the individuals from the energy sector, the snowball sampling technique aids in the identification of key individuals for the research. However, snowball sampling may not be effective in representing the required sample, as the choice of the entire sample rests upon the individuals, who may belong to a specific faction, and thus, present strong biases.⁴⁹¹

The development of the sample was not only based on the accessibility and willingness of the sample population, but also their relevance to the research; people that have direct input into the national energy policy of Oman. Even though the sample size itself was not large, as it was limited to the high-profile officials and the people who have direct influence on energy policy, the research was based on the knowledge that the interviews would be analysed in-depth. According to Pole and Lampard, a focus on a small number of cases and the design of the sample of significant respondents in considerable detail would compensate the limitation of the size.⁴⁹² The sample was designed based on respondents who could have direct or indirect input in energy policy, in addition to those who are representative of the field of energy in Oman, either Omanis or non-Omanis.

5.4.5 Interview sample profile

The objective of this research is to explore the way that the national energy policy is conceptualized and practised within the context of the energy sector in Oman. The sample

⁴⁹⁰ Wilson, J., 2014. *Essentials of business research: A guide to doing your research project*. Sage.

⁴⁹¹ Kumar R.: 2014, *Research methodology, A step-by-step guide for beginners*.

⁴⁹² Lampard, R. and Pole, C., 2015. *Practical social investigation: Qualitative and quantitative methods in social research*. Routledge.

population represents a wide range of respondents from different areas of the energy sector such as the government, academic and private sector.

The interview profile and sample size was considered sufficient to research requirements due to the comparatively small number of experts involved with energy policy in Oman, especially those people directly and solely involved in national energy policy. Therefore, a larger sample size was not necessarily required, as there were few variations among experts and the total population was most likely homogeneous.⁴⁹³

The objective of designing the sample was to gain an accurate and deep understanding of experts from a variety of energy fields. In the year 2015, the current researcher conducted interviews with respondents that have a direct involvement in or influence on the energy diversification policy in Oman, in order to discover their views towards energy diversification policy.

Overall, twenty five interviews were conducted (over the period of May to August 2015). In general, the interviewees, in most cases, were senior in position. The selection standard used was that an interviewee should have either influence over, or a high knowledge of or expertise in Oman's national energy policy processes. The twenty five interviewees included two ministers, two excellences, four CEOs, nine academic professors and their assistants, and eight directors. Table 5-3 illustrates some background information regarding the interviewees.

Table 5- 3: Interviewees' background information

Type	Variable	No. of interviewees
Nationality	Omani	19
	Non-Omani	6
Main Affiliation	Public Sector	11
	Private Sector	5
	Academia	9
Highest academic qualification	Doctoral Degree	17
	Master's Degree	6
	Bachelor's Degree	2

⁴⁹³ Cohen, L., Manion, L. and Morrison, K., 2000. Research Methods in Education, 5th edn (Abingdon: RoutledgeFalmer).

Source: compiled by the author, 2015.

Each of the twenty five interviews lasted between twenty and sixty minutes, and they were all voice recorded and handwritten notes before being transcribed, except for one participant that refused to have his interview recorded. In addition, all interviews were conducted in English, although all were offered the option of conducting the interview in Arabic if preferred.

During the data collection, it is important to keep in mind that the analysis of data from qualitative interviews is often conducted at a number of stages, as new questions are generated from the collected data, requiring further data collection and analysis. An opposite approach is taken for quantitative research, where data collection and data analysis are frequently in order.⁴⁹⁴ However, there are many methods and techniques for data analysis, used for inductive and deductive analytical approaches; and no single method is sufficient for performing data analysis in different situations.⁴⁹⁵ For example, inductive analytical approaches are most likely associated with qualitative research literature that is based on “grounded theory”.⁴⁹⁶ However, numerous researchers have failed to follow the exact steps required in developing a “grounded theory”.⁴⁹⁷ In addition, certain researchers favour using complex qualitative analytical software packages for a small number of interviews (e.g. fewer than fifteen interviews), but the investment required in terms of money, and the time and effort to learn to use the software, was not considered reasonable for the present study. Therefore, for this reason, the current researcher analysed the collected data from the relatively small number of interviews manually by recognizing emerging results, in addition to investigating the differences and similarities between the outputs of the interviews. This analysis was performed in view of the theoretical framework implemented. Hart stresses that by using such a qualitative approach to data analysis, the interviewer should be able to link the interviewees’ responses to the “entire picture” that is developed by the research aims and acknowledged by the analytical framework.⁴⁹⁸

⁴⁹⁴ Thomas, A.B., 2004. *Research skills for management studies*. Psychology Press.

⁴⁹⁵ Marshall, C. and Rossman, G.B., 2014. *Designing qualitative research*. Sage publications.

⁴⁹⁶ Locke, K.D., 2000. *Grounded theory in management research*. Sage.

⁴⁹⁷ Crowther, D. and Lancaster, G., 2012. *Research methods*. Routledge.

⁴⁹⁸ Hart, C., 2005. *Doing your masters dissertation*. Sage.

5.5 Research ethics

As the research involves interviews with people, certain ethical issues regarding the participants were carefully kept in mind during the interview fieldwork process. All interviews were conducted in accordance with the King's College London Guidelines on Good Practice in Academic Research. One of the main requirements of the guidelines is that the researcher must notify the participants about the research objectives in advance. Thus, all participants were informed of the scope of the research study and the aims, and the opportunity was given for the participants to ask questions in advance. They also were informed that the research is for academic purposes and that all the information gathered would be kept confidential.

Another ethical consideration that was applied in the early procedures of this research was getting approval from King's College London to conduct the interviews. For this reason, the ethical clearance application was filled in (ethics application approval number: REP/14/15-101). It is essential to take this step prior to interviewing any participants to collect the required information. For example, high-profile officials and policy-makers who are involved in energy sector, which were all approached formally by an official letter from the researcher's governmental institute, The Research Council of Oman.

One important factor to bear in mind that the research area deals with topics that respondents might view as sensitive. For example, highlighting certain themes in the interviews might result in the respondents attempting to avoid answering politically sensitive questions. Thus, ethical practices should be considered and abided by in all circumstances. Claire and Raymond argued that when dealing with sensitive topics, the researcher must maintain consideration for the anonymity of the respondents.⁴⁹⁹ This means that, at the beginning of each interview, the interviewer should put emphasis on the fact that the respondents' identities will not be exposed in the thesis, if this is the preference of the respondent. This approach was implemented and helped to gain the confidence of interviewees, which resulted in greater openness of interviewee's and the sharing of thoughts and views.

⁴⁹⁹ Lee, R.M., 1993. *Doing research on sensitive topics*. Sage.

Paul emphasized other ethical bases that could weaken the quality of data collection and analysis.⁵⁰⁰ For instance, fabricated or fraudulent materials, and the omission of information are both unscientific and unethical in any research field. It is also important that the level of data accuracy be as high as possible. It is possible that interviewees may try to provide the types of answers they believe the interviewer wants to hear. Therefore, the interviewer assured all participants at the beginning of each interview that talking freely is encouraged, and there are no right or wrong answers to any of the questions.

5.6 Research Rigours

All scientific research is liable to rigour tests.⁵⁰¹ However, the type of tests that are implemented on qualitative and quantitative research is under continues debate.⁵⁰² According to Mays and Pope, a rigour test should assess the reliability and validity of the research.⁵⁰³ Krefting thinks that reliability and validity are closely related to each other so that validity only exists with reliability⁵⁰⁴—ie, if the data is not reliable, then it cannot be valid. Lincoln and Guba propose other measures that can be used to assess the trustworthiness of qualitative research, including credibility, confirmability, dependability, and transferability.⁵⁰⁵ Morgan argues that the characteristic features of a qualitative case study is evidence gathered to create internally valid accounts, which are consistent, coherent, and credible.⁵⁰⁶

Nahid agrees that the validity and reliability tests for qualitative case study research are necessary, but argues that these tests require different approaches for quantitative and qualitative research, therefore, those used for quantitative research need to be redefined for

⁵⁰⁰ Oliver, P., 2010. *The student's guide to research ethics*. McGraw-Hill Education (UK).

⁵⁰¹ Morgan, M.S., 2012. Case studies: One observation or many? Justification or discovery?. *Philosophy of Science*, 79(5), pp.667-677.

⁵⁰² Taylor, S.J., Bogdan, R. and DeVault, M., 2015. *Introduction to qualitative research methods: A guidebook and resource*. John Wiley & Sons.

⁵⁰³ Mays, N. and Pope, C., 1995. Qualitative research: rigour and qualitative research. *Bmj*, 311(6997), pp.109-112.

⁵⁰⁴ Krefting, L., 1991. Rigor in qualitative research: The assessment of trustworthiness. *American journal of occupational therapy*, 45(3), pp.214-222.

⁵⁰⁵ Morehouse, R.E. and Maykut, P., 2002. *Beginning qualitative research: A philosophical and practical guide*. Routledge.

⁵⁰⁶ Morgan, M.S., 2012. Case studies: One observation or many? Justification or discovery?. *Philosophy of Science*, 79(5), pp.667-677.

qualitative research.⁵⁰⁷ Nahid also stresses that a rigour test can be defined by research paradigm—ie, by assuming how research should be conducted. Healy and Perry believe that the quality of a study in each paradigm should be evaluated by its own tests.⁵⁰⁸ Similarly, Johnson argued that the purpose of qualitative research is to engage in research that aims to deepen understanding and discover meaning rather than examine surface features, such as substantiating the truth or predicting results.⁵⁰⁹ Myers asserted this view by saying that qualitative research is dependent on its own exact epistemological reflections and has its own views on ways to share knowledge with society.⁵¹⁰

Clearly a consensus has not been achieved between scholars and researchers on how to guarantee the rigour of qualitative research. As emphasised by Helen and Joanna, "there are ongoing debates about whether terms such as validity, reliability and generalisability are appropriate to evaluate qualitative research".⁵¹¹ The terms validity, reliability, and generalisability, which have been used in the literature, might lead to misperception by scholars and researchers because they generally can be used interchangeably and so are vague.

For the purpose of this research, the four important rigour tests of reliability, credibility, validity, and triangulation have been adopted.

5.6.1 Reliability

Reliability is the likelihood that, if research is repeated with the same participants, under the same circumstances, and adopting similar approaches, it will produce similar results over time.⁵¹² However, it is difficult to assess the reliability of qualitative research when reliability is achieved by replicating results, because by nature, qualitative research conditions are not

⁵⁰⁷ Golafshani, N., 2003. Understanding reliability and validity in qualitative research. *The qualitative report*, 8(4), pp.597-606.

⁵⁰⁸ Healy, M. and Perry, C., 2000. Comprehensive criteria to judge validity and reliability of qualitative research within the realism paradigm. *Qualitative market research: An international journal*, 3(3), pp.118-126.

⁵⁰⁹ Johnson, R.B., 1997. Examining the validity structure of qualitative research. *Education*, 118(2), p.282.

⁵¹⁰ Myers, M., 2000. Qualitative research and the generalizability question: Standing firm with Proteus. *The qualitative report*, 4(3), p.9.

⁵¹¹ Noble, H. and Smith, J., 2015. Issues of validity and reliability in qualitative research. *Evidence-Based Nursing*, pp.ebnurs-2015.

⁵¹² Bryman, A., 2016. *Social research methods*. Oxford university press.

constant. In addition, the interpretive nature of qualitative research, which is employed in this study, cannot be easily replicated by different researchers because each individual might perceive and interpret views differently. However, reliability can be enhanced by using procedures such as triangulation and methodological rigour to assess the robustness of findings obtained from a specific approach.⁵¹³

Lewis et al. (2007) stress that it is very unlikely that research will be replicable when it is carried out using an interpretivism paradigm.⁵¹⁴ Similarly, Edward and Richard state that “The amount of chance error may be large or small, but it is universally present to some extent. Two sets of measurements of the same feature of the same individuals will never exactly duplicate each other”.⁵¹⁵ The interviews conducted in this research required interactions with respondents. Human behaviour is changeable and unpredictable, which makes the replication of the research results almost impossible. Regardless, reliability is the most commonly used rigour test in all types of research.⁵¹⁶

The present research applies the suggestions of Noble and Smith (2015), Myers (2000), Mays and Pope (1995), and Krefting (1990) on observing consistency and stability as the criteria concerned with qualitative research. The stability and consistency of research is described by Rambaree as to “ensure that data collection is undertaken in a consistent manner free from undue variation which unknowingly exerts an effect on the nature of the data”.⁵¹⁷ Furthermore, tools that are investigated for consistency in qualitative research are the researcher and the participants, both of whom differ greatly with each study.⁵¹⁸ Therefore, reliability in qualitative research confirms that the outlying data needs to be identified to describe the boundaries of the experiences or phenomenon, meaning that the stability of data collected rather than identical

⁵¹³ Berg, B.L., Lune, H. and Lune, H., 2004. *Qualitative research methods for the social sciences* (Vol. 5). Boston, MA: Pearson.

⁵¹⁴ Saunders, M., Lewis, P. and Thornhill, A., 2009. *Research methods for business students*. Pearson education.

⁵¹⁵ Carmines, E.G. and Zeller, R.A., 1979. *Reliability and validity assessment* (Vol. 17). Sage publications.

⁵¹⁶ Golafshani, N., 2003. Understanding reliability and validity in qualitative research. *The qualitative report*, 8(4), pp.597-606.

⁵¹⁷ Rambaree, K., 2007. Bringing Rigour in qualitative social research: the use of a CAQDAS. *University of Mauritius Research Journal*, 13(1), pp.1-16.

⁵¹⁸ Krefting, L., 1991. Rigor in qualitative research: The assessment of trustworthiness. *American journal of occupational therapy*, 45(3), pp.214-222.

repetition is sought.⁵¹⁹ Therefore, the researcher attempted to increase the reliability by adopting the following steps:

1. Ensure clear understanding by the interviewee of the nature of the research through clear explanation of the components of the research, including themes, research and interview questions, sampling, data collection methodology, and reporting.
2. Interview the same respondent on several occasions and make individual and overall observations for the interviews.
3. Compare the results with other evidence from previous studies.
4. Compare findings and analysis with those of other respondents from this study.
5. Keep accurate and detailed field notes to recognise the differences in responses over time.
6. Ensure that the objective of the research, research questions, and data collection and analysis are all consistent, to provide the same results.

5.6.2 Credibility

Credibility is defined as “the confidence that can be placed in the truth of the research findings”.⁵²⁰ In other words, the capability of researchers to deliver plausible information produced from the respondents’ original data and is a correct interpretation of the respondents’ original views. Long and Johnson asserted this view by stating that” the plausibility of the findings is reliant upon the interpreted, analysed data being recognisably drawn from the raw data, and is demonstrated partly by evidence of stringent efforts to ensure this”.⁵²¹ The researcher applied different measures to ensure the credibility of the present research, including:

1. Applied the most appropriate and well-established research design in order to have the research questions answered and achieving study objectives.

⁵¹⁹ Anney, V.N., 2014. Ensuring the quality of the findings of qualitative research: Looking at trustworthiness criteria.

⁵²⁰ Long, T. and Johnson, M., 2000. Rigour, reliability and validity in qualitative research. *Clinical effectiveness in nursing*, 4(1), pp.30-37.

⁵²¹ Carmines, E.G. and Zeller, R.A., 1979. *Reliability and validity assessment* (Vol. 17). Sage publications.

2. Adopted “prolonged engagement” procedure that allowed the researcher to learn traditions and customs of the respondents and build trust so the researcher becomes familiar with the situation and understands and appreciates the context.
3. Gathered data from various participants, including Omanis and non-Omanis from the government, academia, and the private sector, across different hierarchical levels.
4. Adopted “persistent observation” procedure allowing the researcher to examine and look in depth at the data to ensure that the data is most relevant to the problem or issue that is being investigated.
5. Applied “peer debriefing”, which is the procedure that the researcher uses by asking the supervisor to check for any bias introduced by the researcher and to ensure results reflect the data.
6. Implemented “negative case analysis” procedure that allows the researcher to look carefully over the case and present information from an interview that does not always necessary to align with the themes, because not all the data will yield the same results.
7. Adopted “referential adequacy” procedure, which is a method used to store field notes or interview voice records to assess later and compare with any future research to show the credibility of data.
8. Applied “member checking” procedure, where the researcher asks the participants to review the data, analytic themes, interpretations, and test results from other participants. This procedure allows the researcher to assess the overall accuracy of the information and verify data results.
9. Discussed progress made and findings with supervisor
10. Take courses to enhance skills on managing interviews and note taking.

5.6.3 Validity

Edward and Richard (1987) defined reliability as the capability of the measuring instrument to measure what it should measure.⁵²² Lawrence (2015) refers to the validity as the appropriateness of the measures, processes, and data. He noted that the research question should be valid for the desired outcome, the selection of methodology should be appropriate

⁵²² Leung, L., 2015. Validity, reliability, and generalizability in qualitative research. *Journal of family medicine and primary care*, 4(3), p.324.

for answering the research question, the design should be valid for the methodology, the sampling and data analysis should be appropriate, and the overall results and conclusions should be valid for the context.⁵²³ Creswell described this view of the validity of an instrument by saying that the information obtained by research should accurately align with the situation or phenomenon being investigated.⁵²⁴ In other words, if the measuring instrument does not have the ability of what is supposed to measure, then the research could have some difficulties in terms of the validity of the results. Thus, the researcher took different steps to ensure the validity of the research, including:

1. Ensured the research objectives were clearly defined and operationalised.
2. Ensured the alignment of research objectives with the current literature, questions, methodology, and data collection and analysis.
3. Developed a provisional list of themes or an initial scope of work that steered the processes of empirical data collection and analysis.
4. Ensured the alignment of themes with the present literature and that they reflected the overall research objectives.
5. Shared the interview questions and themes with a skilled facilitator to ensure neutrality and minimal personal bias, so responses are genuine and not influenced by what the investigator wants to hear.
6. Consulted my supervisor and three experts (two from government sector and one from academia) from the energy sector about the development of themes and interview questions and amended the changes on the basis of the feedback.
7. Ensured that the questions were clearly understood by the participants and confirmed their answers.
8. Tested initial results with participants who had the chance to discuss and recognise the interpretations (analysis) as authentic.
9. Ensured saturation of responses occurred so the data become more reliable.

⁵²³ Creswell, J.W. and Creswell, J.D., 2017. *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage publications.

⁵²⁴ Berg, B.L., Lune, H. and Lune, H., 2004. *Qualitative research methods for the social sciences* (Vol. 5). Boston, MA: Pearson.

5.6.4 Triangulation

One way to enhance the quality and validity of research is through adopting the triangulation method. Denzil defines triangulation as “the use of two or more data sources, methods, investigators, theoretical perspectives and approaches to analysis in the study of a single phenomenon and then validating the congruence among them”.⁵²⁵ Yin (2014)⁵²⁶ and Patton (2002)⁵²⁷ identified four types of triangulation. Theory triangulation (involves adopting multiple perspectives in the interpretation of the phenomenon) helps to look at a situation or phenomenon from different perspectives, through different lenses, with different questions. Data source triangulation (involves using different types of participants or different sources of data) helps in identifying and strengthening the respondents’ interpretations or information by cross-checking results and confirming findings. Investigator triangulation (using more than one researcher in an investigation) helps to decrease bias when collecting, reporting, or analysing data. Methodological triangulation (using multiple methods or data collection techniques to investigate a situation or phenomenon) helps to decrease the deficiencies and biases that are inherent in any single method.

The main purpose of using the triangulation method is to minimise personal bias of the researcher and minimise any missing evidence or gaps in knowledge that could have been present, thus increasing the validity and accuracy of the research study.⁵²⁸ This study adopts several methods of triangulation to increase validity and accuracy, including:

1. Gathering data from different sources, including documents, annual reports, archives, statistical year books, and academic publications or other notes obtained from individual participants or organisations.
2. Conducting interviews from different sectors, including the private sector, government, and academia, with different work experiences from local Omani citizens and non-Omani expatriates.

⁵²⁵ Yin, R.K., 2017. *Case study research and applications: Design and methods*. Sage publications.

⁵²⁶ Patton, M.Q., 2002. *Qualitative research & evaluation methods*, 3rd edn.(Sage Publications: Thousand Oaks).

⁵²⁷ Shenton, A.K., 2004. Strategies for ensuring trustworthiness in qualitative research projects. *Education for information*, 22(2), pp.63-75.

⁵²⁸ Ibid

3. Interviewing more than one participant from each organisation to ensure a strong conclusion about the findings obtained and to reduce the risk of wrong interpretations.
4. Conducting one interview with a non-energy expert participant to provide a layperson view and to ensure understanding of the research problem by the interviewee.
5. Conducting two interviews (one retired senior director from the oil company PDO, and the other an active senior director from the oil and gas ministry of the Omani Government) to help explain, refuse, and confirm the results attained from the field.

5.7 Research limitations and issues

Several obstacles had to be overcome in the current research while carrying out interviews, which were conducted with individuals involved in decisions within the context of energy issues, as well as policymakers in Oman.

First, the interview was designed for high-profile officials and policymakers, but these individuals do not have much spare time. The procedures for communication with these participants were very slow, and took far more time than expected. Once the interviewer requests an interview with high-profile officials or a general director, the waiting time for approval of the interview commonly lasts between four and six weeks, but occasionally is successful in two weeks. This created a clash of appointments on several occasions. This happened when the interviewer received an approval to meet a high-profile official on a day that another meeting was already scheduled, so the interviewer had to postpone one meeting resulting in an extended wait of four weeks. Thus, one of the most important lessons the researcher learned during the interview fieldwork was that meetings with high-profile officials must be carefully planned, with all alternative options and outcomes considered. For example, three visits had to be made to follow up the request to meet one minister.

Second, all interviews were tape recorded except one. However, two interviews took place in a public place such as a coffee shop, as the interviewees preferred. These two interviews were difficult to transcribe precisely because of the level of noise. The problem of noise was great; there were interruptions from machines or telephones, which resulted in difficulties hearing and understanding the interviewee.

The third problem the researcher faced with certain interviewees was that, although they were transparent and relatively open in sharing their views and experiences when talking in general about the energy sector in Oman, they intended to be more conservative and cautious when discussing in-depth details of energy performance, such as the energy prices and subsidies in Oman. They felt that the driving force for cheap energy prices in Oman was more political than economical. Therefore, a number of the interviewees were careful not to discuss the issue of energy prices. This is probably due to reluctance to discuss the politics of the country, and they were cautious not to undermine the government's decisions when discussing these issues. To overcome this issue and ensure that the interviewees spoke more freely about their experiences and knowledge, the researcher assured the participants that the purpose of the research was purely academic, and not to discuss the politics of the country. In addition, for further assurance, the researcher provided a brief talk about the nature and main aims of the project, and how important the interviewees' contributions would be; that they would be of great help not only for the success of the research, but that the whole country would benefit from the outcome. The majority of the interviewees responded well to these assurances and shared good information, yet others remained restrained.

5.8 Conclusion

The research method adopted is based, in terms of exploring the topic as well as data gathering and analysis, on the qualitative approach, which was deemed the most suitable option for this research. The above chapter justifies the selected research methods and its implementations for the purpose of obtaining the required information. Both primary and secondary data collection methods were used to ensure the validity and credibility of all the results gained from this research. The interview technique was adopted, as this is not only a commonly used technique for the collection of information from individuals, but also has the ability to perform as a complementary instrument, aiding the identification of missing knowledge and information that could not be obtained through other research methods, such as secondary data collection. In addition, the sampling method was adopted as a tool to ensure that the sample provided significant relevance to this research, and it represents a wide range of respondents from different sectors across the energy field, such as government, academic and private sector employees. The chapter also covers the research limitations and issues, along with ethical issues raised while conducting the field work.

Chapter 6

Energy and Socioeconomic Development Planning Policies

6.1 Introduction

This chapter provides the first part of the empirical findings of this research, analysing the factors that hinder the energy sector in terms of achieving energy sustainability. The importance of planning policies is highlighted in most sustainable energy development literature, because policy planning is the guiding tool for sustainable development (Pohekar & Ramachandan, 2004;⁵²⁹ Afga & Carvalho, 2000;⁵³⁰ Gobaisi et al., 1998;⁵³¹ Goran, 2008⁵³²). Achieving energy sustainability requires organised planning and implementation. This chapter examines the performance of the economy in terms of energy and analyses the development planning policies of each 5-year development plan and the Vision 2020 in relation to its challenges and contradictions.

Despite the stable and positive macroeconomic indicators in Oman over the past four decades, the Omani economy still faces many difficulties. Concerns are growing about the government's increasing expenditure in general infrastructure (paving roads, building hospitals and schools, desalinating water, and building new power plants) resulting from a push for economic development and also the increase in salaries of government employees, which account for 72% of total civil expenditure.⁵³³ Furthermore, the increase in spending was accompanied by a decrease in oil revenues of at least 40% in 2015 compared with the previous year.⁵³⁴ These facts highlight a pressing need for the government to not only fix its employees' salaries, but also to overcome the problem of the unsustainable energy sector.

Similar to its neighbouring Gulf Cooperation Council (GCC) countries, Oman's economy relies heavily on oil and gas export revenues, and the core player in the economic sector is the government, with broad control over many main economic activities. The oil and gas sector

⁵²⁹ Pohekar, S.D., Ramachandran, M., 2004. Application of multi-criteria decision making to sustainable energy planning - A review. *Renewable and Sustainable Energy Reviews*. doi:10.1016/j.rser.2003.12.007

⁵³⁰ Afgan, N.H. and da Graça Carvalho, M., 2000. Energy system assessment with sustainability indicators. In *Sustainable Assessment Method for Energy Systems* (pp. 83-125). Springer, Boston, MA.

⁵³¹ Afgan, N.H., Al Gobaisi, D., Carvalho, M.G. and Cumo, M., 1998. Sustainable energy development. *Renewable and sustainable energy reviews*, 2(3), pp.235-286.

⁵³² Strbac, G., 2008. Demand side management: Benefits and challenges. *Energy policy*, 36(12), pp.4419-4426.

⁵³³ CBO (2015) Annual report. Muscat: Central Bank of Oman.

⁵³⁴ NCSI (2016) Statistical yearbook. Muscat: National Centre for Statistics and Information.

remains the greatest contributor to the Omani economy, in terms of budget revenues, exports, and GDP. The oil and gas sector accounted for about 40% of GDP, 79% of government revenue, and 60% of total merchandise exports in 2015.⁵³⁵ The breakeven price required to balance the budget for the oil and gas sector has been increasing over the past decade because of increasing costs associated with production. According to the International Monetary Fund (IMF), the breakeven price for a barrel of oil was US\$79 in 2012 and \$96 in 2015.⁵³⁶ In addition, a sharp decline in global oil prices occurred between 2014 and 2016 because of abundant supply from the Organization of Petroleum Exporting Countries (OPEC) and Russia, as well as anticipated increasing supply from Iran, leading to weakened international demand. As a result, Oman has suffered significant losses in oil export revenues and overall economic activity. According to the Central bank of Oman, oil prices declined by 45.3% to US \$56.50 per barrel in 2015 from \$103.20 per barrel in 2014, reflecting a fiscal deficit of 17.1% (OMR 4.2 billion).⁵³⁷ The Omani government managed to finance 70% of its overall deficit by drawing down reserves while financing the remaining 30% through loans, grants, and residual surplus from 2014. However, losses are reached 10% of Omani GDP in 2018, according to the IMF.⁵³⁸

In addition to its reliance on oil export revenues, Oman also faces the major challenge of increasing domestic energy demand. This increase is mainly due to low energy prices, economic expansion, inefficient energy-consuming technology and equipment such as air conditioners, population growth, increased average income, and the hot climate. Energy prices directly influence energy consumption; if prices are low, people use more fuel and electricity. Similarly, the price also indirectly affects consumption; low prices allow people to afford to buy equipment that consumes more energy and they are less concerned about the level of efficiency of that equipment.⁵³⁹ With no doubt, Oman acts as a rentier state (ie, a state that

⁵³⁵ CBO (2015) Annual report. Muscat: Central Bank of Oman.

⁵³⁶ International Monetary Fund (IMF). (2017). Regional economic outlook. Middle East and Central Asia. [online] Available at: <https://www.imf.org/en/Publications/REO/MECA/Issues/2017/10/17/mreo1017> [Accessed 6 Sep. 2018].

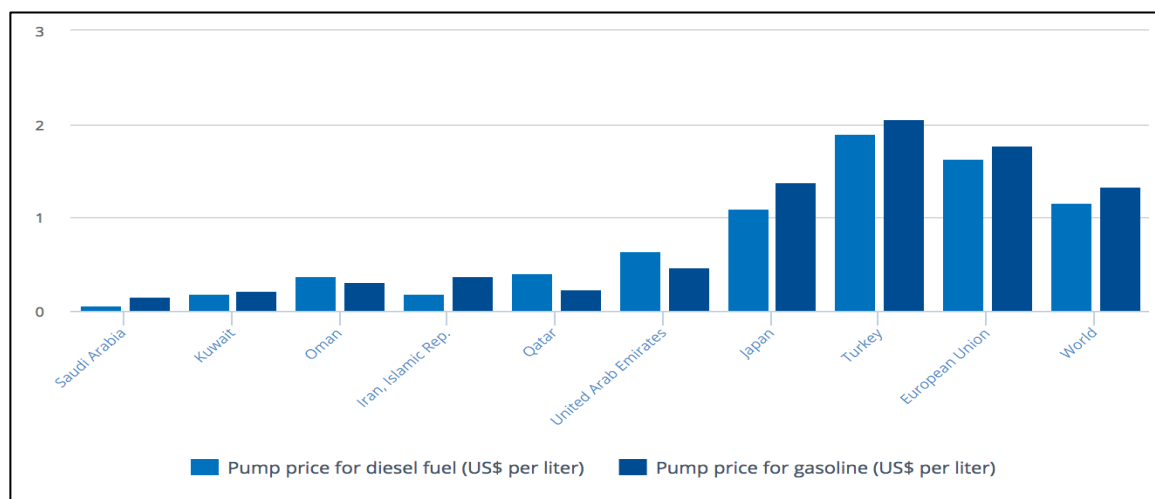
⁵³⁷ CBO (2015) Annual report. Muscat: Central Bank of Oman.

⁵³⁸ International Monetary Fund (IMF). (2017). Regional economic outlook. Middle East and Central Asia. [online] Available at: <https://www.imf.org/en/Publications/REO/MECA/Issues/2017/10/17/mreo1017> [Accessed 6 Sep. 2018].

⁵³⁹ Hunt, L.C. and Evans, J. eds., 2011. International handbook on the economics of energy. Edward Elgar Publishing.

derives most of its national revenues from selling a natural resource to other countries) as do its neighbouring energy-rich countries. The Omani government directly redistributes the income from petroleum to its citizens by subsidising energy products.⁵⁴⁰ This type of policy is very common in hydrocarbon-rich countries, where the citizens usually feel a sense of a right to hydrocarbons.⁵⁴¹ The Omani government redistributes the hydrocarbon rent that it gets from other countries to its residents through cheap diesel and petrol prices, and as a result, Oman has some of the lowest fuel prices in the world, as shown in Figure 6-1. Furthermore, electricity production companies benefit from fuel subsidies, which are passed on as low energy prices for their customers.

Figure 6- 1: Pump prices for diesel and petrol in 2014 (in US\$ per litre)



Source: World Development Indicators, World Bank (2017)

According to Gianluca and Luca, one of the resource curse symptoms that can affect the economy is the high level of subsidies that are directed towards the energy sector.⁵⁴² For example, the subsidies that are provided by the Omani government are highly inefficient and unsustainable. In 2015, subsidies accounted for US\$1 billion of the government's expenditure or about 3.7% of Oman's GDP, compared with US\$ 600 million in 2012.⁵⁴³ In other words, costs related to subsidies are rapidly increasing every year in an unsustainable manner, putting an incremental fiscal burden on the government, who bridge the gap between energy production costs and local selling prices⁵⁴⁴. In addition, subsidies encourage energy consumers to consume more energy, creating bad habits

⁵⁴⁰ Luciani, G. and Beblawi, H., 1990. *The Rentier State in the Arab World. The Arab State*. London: Routledge.

⁵⁴¹ Segal, P., 2012. How to spend it: Resource wealth and the distribution of resource rents1. *Energy Policy*, 51, pp.340-348.

⁵⁴² Benigno, G. and Fornaro, L., 2014. The financial resource curse. *The Scandinavian Journal of Economics*, 116(1), pp.58-86.

⁵⁴³ Rodriguez, S., Pant, M. and Flores, J., 2015. *Energy Price Reforms in the GCC: What Can Be Learned from International Experiences*. International Monetary Fund, Washington.

⁵⁴⁴ In year 2015 subsidies on housing loans, utility bills, oil and gas, and other goods and services are representing about 8% of the total state budget.

of high energy consumption and at the same time undermining the call for energy conservation. According to the minister of financial affairs of Oman, “the negative aspects of subsidies are numerous. They lead to overconsumption or misuse of petroleum products, overcrowding of roads, and a growing number of vehicles on the roads”.⁵⁴⁵ In addition, Maggio and Cacciola confirms in their oil peak approach that the peak of world crude oil would be reached faster due to inefficient energy subsidies.⁵⁴⁶

Since the first commercial shipment of Omani oil in 1967, Omani oil production increased and decreased over the proceeding four decades. Between the 1980s and 1990s, oil production doubled from 300,000 bpd to 700,000 bpd, and then continued to increase to 960,000 bpd by 2000.⁵⁴⁷ Oman is not a member of the Organization of the Petroleum Exporting Countries (OPEC), allowing it to increase its oil production without limits. However, oil production peaked in 2001 (see chapter 2 section 3.1), and gradually declined to 710,000 bpd by 2007, at which point about 62% of Omani oil reserves had been depleted, according to Campbell in his book *Campbell’s Atlas of Oil and Gas Depletion*.⁵⁴⁸ The remaining oil is likely to continue to decline at the present depletion rate of 5% per year. However, this prediction is probably lower than the actual rate, because Petroleum Development Oman (PDO) has adopted enhanced oil recovery (EOR) techniques, increasing oil production further. The average daily oil production grew from 710,000 bpd in 2007 to 1 million bpd in 2015.⁵⁴⁹ These techniques of EOR and advanced drilling technologies could unlock more oil in a shorter time, but will speed the inevitable decline of resources. Campbell’s estimation of Omani oil reserves was just 1.6 billion barrels, compared with estimations of 5.5 billion barrels in other publications, which is suggested in the literature of oil peak theory that the highest point of oil production could be passed and the decline trend took place already.⁵⁵⁰

Different opinions exist about oil and gas reserves and no one can predict accurately when extraction will lead to total depletion, but it will happen at some point in the future. According

⁵⁴⁵ ArabianBusiness.com. (2014). Oman to review fuel subsidies. [online] Available at: <https://www.arabianbusiness.com/oman-review-fuel-subsidies-533543.html> [Accessed 6 Sep. 2018].

⁵⁴⁶ Maggio, G. and Cacciola, G., 2012. When will oil, natural gas, and coal peak?. *Fuel*, 98, pp.111-123.

⁵⁴⁷ Bakhtiari, A.S., 2003. Middle East oil production to peak within next decade. *Oil & Gas Journal*, 101(26), pp.20-20.

⁵⁴⁸ Campbell, C.J. and Wöstmann, A., 2013. *Campbell's atlas of oil and gas depletion* (p. 788). New York: Springer.

⁵⁴⁹ Eia.gov. (2017). Oman - International - Analysis - U.S. Energy Information Administration (EIA). [online] Available at: <https://www.eia.gov/beta/international/analysis.php?iso=OMN> [Accessed 6 Sep. 2018].

⁵⁵⁰ Campbell, C.J. and Wöstmann, A., 2013. *Campbell's atlas of oil and gas depletion* (p. 788). New York: Springer.

to a scholar at the University of York, there is no doubt that one day hydrocarbons will be depleted and the world's demand for them will not be fulfilled, the only question is a matter of when that point will be reached.⁵⁵¹ In addition, Tim et al. argued that one of the symptoms of the resource curse theory is the sustainability of a resource long-term survival, confirming that oil and gas resources do not fall under the criteria of sustainability.⁵⁵²

6.2 Development planning policies

Before the 1970s, under the former Sultan, policies for economic development and modernisation of the country were very conservative in terms of resource use. The former Sultan did not use funds to improve conditions in Oman because he was not interested in modernisation and kept the country isolated from the world. Even after the start of oil exportation in 1967 and the new opportunities that oil revenues offered, the conservative expenditure policies limited the effects of the increased revenues, resulting in slow and minimal development. However, since Sultan Qaboos bin Said al Said came to power in the mid-1970s, he has ensured that the government has input policies that encourage development, coupled with significant increases in government expenditure.⁵⁵³

Thus, the absence of a diverse variety of resources in Oman and the pressing need to accelerate the wheel of development has forced the Omani government to execute development planning to allocate strategic resources that could drive the national economy. The need for development planning became clear on recognition of the absence of basic social and economic infrastructure and health and education facilities, alongside diminishing resources and the barely existent private sector.⁵⁵⁴

In the early 1970s, no sole entity took full responsibility for governmental operations and processes, but planning and executive actions were spread across different institutes. In 1974,

⁵⁵¹ Shafiee, S. and Topal, E., 2009. When will fossil fuel reserves be diminished?. *Energy policy*, 37(1), pp.181-189.

⁵⁵² Prior, T., Giurco, D., Mudd, G., Mason, L. and Behrisch, J., 2012. Resource depletion, peak minerals and the implications for sustainable resource management. *Global Environmental Change*, 22(3), pp.577-587.

⁵⁵³ Documents.worldbank.org. (2018). Oman: Transformation of an Economy. [online] Available at: <http://documents.worldbank.org/curated/en/382701468333631479/pdf/multi0page.pdf> [Accessed 6 Sep. 2018].

⁵⁵⁴ MOI (2013) Oman Book. Muscat: Ministry of information.

however, the Development Council was established to preside over the country's development plans. The main responsibility of the planning entity, according to Seers, is to be "the nervous centre of the government machine, continually scanning experience and helping the government adjust its policies accordingly, in the light of a long-term strategy".⁵⁵⁵ The Development Council was chaired by Sultan Qaboos bin Said al Said, not only to ensure that plans were efficient and aligned with current government policies but also to provide the Development Council with the political weight required to control and arrange the activities of various governmental bodies. This initial structure has contributed positively to the successful implementation of public investment programmes that were established in sequential development plans.

Under Oman's planning system, the Development Council played the main role of setting long-term objectives of development and formulating the 5-year development plans of Vision 2020. The main role of the Financial Affairs Council was to set short-term and medium-term fiscal policies, and the Ministry of Finance and Economy was responsible for allocating resources for public expenditure.⁵⁵⁶

However, the implementation of all development planning policies and strategies have been fuelled largely by the revenues that are being generated from the export of oil and gas commodities. This can be a problem because the implementation processes of policies and strategies are long-term goals (5 years), whereas fluctuations of oil prices in the global market occur on a much more short-term basis, and can have a severe effect on the funds available for these social and economic activities. The Omani government has to plan to ensure that inflation is manageable, fiscal deficits and external debt are under control, and the growth rate of the overall development is maintained, or the national economy would not be able to cover growing domestic expenditures. For example, because of the low oil prices in the global market, Oman announced publicly in 2017 that a loan of US\$3.55 billion has been taken from a group of Chinese financial institutions to cover its budget deficit for the current fiscal year,

⁵⁵⁵ Seers, D., 1972. PREVALENCE OF PSEUDO-PLANNING. *New Society*, 20(503), pp.352-354.

⁵⁵⁶ World Business and Investment Library. (2016). [online] Available at: <https://www.amazon.com/Oman-Criminal-Regulations-Procedures-Handbook/dp/1514507757> [Accessed 6 Sep. 2018].

which in return, Oman must pay back over a 5-year period with a high interest rate.⁵⁵⁷ In other words, a decline in prices of oil and gas exports caused decreases in government revenues, which then resulted in reductions in both overall development and financial commitments to maintain what has been achieved for the past 40 years. Thus, one of the pillars of the development planning policies is to reduce the heavy dependence on oil and gas revenues by diversifying the source of income. The main long-term strategic objectives of these development planning policies are as follows:⁵⁵⁸

- To promote the diversification of the economy by accelerating growth of the non-oil sector, so less dependence upon oil exports can be achieved
- To support Omani human resource development
- To expand the development of the private sector and privatisation of existing government divisions
- To effectively use the commodities generated from petrochemicals and oil and gas to achieve sustainable economic growth and stability.

These policies were initially established by the government to create a rapid push for development and modernisation in terms of improving social and economic infrastructure to link the major population and economic centres with the country, providing health and education services, supplying water and electricity, and opening up the country to the outside world, which did not happen at all before 1970.⁵⁵⁹

6.2.1 The 5-year development plans (1976–1995)

The following sections analyse the development planning policies of Oman (1976–1995) and Vision 2020 (1996 onwards) with reference to empirical evidence from primary data (interview findings) as well as secondary data from Omani publications and academic arguments. Oman's social and economic development plans are in the form of short-term and long-term

⁵⁵⁷ Gulf News. (2017). Oman signs \$3.55b loan with Chinese banks. [online] Available at: <https://gulfnews.com/business/economy/oman-signs-3-55b-loan-with-chinese-banks-1.2068643> [Accessed 6 Sep. 2018].

⁵⁵⁸ CBO (2010) Annual report. Muscat: Central Bank of Oman.

⁵⁵⁹ Documents.worldbank.org. (2018). Oman: Transformation of an Economy. [online] Available at: <http://documents.worldbank.org/curated/en/382701468333631479/pdf/multi0page.pdf> [Accessed 6 Sep. 2018].

development plans. The short-term social and economic development is coordinated through a series of 5-year development plans. Each 5-year development plan identifies the parameters within which annual national budgets are determined (including the permitted budget deficits and withdrawals from general reserves to address the deficits), within the strategic parameters identified in the long-term Vision 2020 goals. Before 1970, Oman was populated with 658,000 people spread over 309,500 km². There were only 10 km of paved roads, 12 hospital beds in one hospital, three schools, one telephone line for every 1,000 users, and few had access to electricity and water. GDP was about US\$270 million and income per capita was about \$415.⁵⁶⁰

One of the main actions that Oman took immediately after 1970 was the creation of the governmental institutions to oversee the development plans. First, a new administration was set up to perform the various administrative and executive tasks of government in general, and to plan and implement the economic and social development projects. Second, a Supreme Council for Economic Planning and Development was established in 1972 to start a process of immediate economic and social development, which was then replaced in 1974 by the Development Council. The core objectives of the Development Council were to plan and draw strategies for social and economic development, to suggest policies and measures to perform these objectives, and to set development policies in harmony with these objectives.⁵⁶¹ A royal decree was issued in 1975 that introduced the Law of Administrative Organisation of the Omani Government. The law described the roles of the government administration and functions of the heads of the administrative bodies.

First 5-year development plan (1976–80): The first five-year development plan was the cornerstone for the development of general infrastructure in Oman, because the country did not have basic infrastructure, institutions, or modern facilities. According to Calvin and Allen, “Oman had a huge need for almost everything”.⁵⁶² New infrastructure was essential as the starting step towards sustainable development, including access to electricity, roads, hospitals, schools, water desalination, social services, and houses.⁵⁶³ These were the main goals of the

⁵⁶⁰ MD (1996) Socio-Economic Atlas, Information and Documentation Centre. Muscat: Ministry of Development

⁵⁶¹ MOCI (1976) Commercial Business Laws of Oman. Muscat: Ministry of Commerce and Industry.

⁵⁶² Allen Jr, C.H., 2016. *Oman: the modernization of the sultanate*. Routledge.

⁵⁶³ Al-Yousef, M.B.M., 1997. *The state and market in Oman's development: conflict or cooperation?* (Doctoral dissertation, University of London).

Omani government in its first 5-year development plan, given the strong expectation that the new ruler would change the country quickly, especially because Oman benefited from the oil boom during this period. An interviewed governmental official gave his view on the first plan:

“I believe the first 5-year development plan was very successful because one of the significant achievements was the establishment of the State General Reserve Fund, which aims to manage and invest the financial surplus gained from oil and gas revenues in ensuring economic stability and achieving sustainability” (IO132, 2015).⁵⁶⁴

A participant from an oil company shared his view on the initial plan:

“I think when starting the development of a country, a sustainable source of income is required, which in our case is the oil and gas revenues. But these revenues are not stable because of the ups and downs of the international oil prices. So, I think the State General Reserve Fund was a very wise idea to ensure the stability and sustainability of socioeconomic development” (IOC1, 2015).⁵⁶⁵

However, although the government benefited from an increase in global oil prices during the 1976–80 5-year developmental period, some challenges had to be faced in the implementation phase, attributed mainly to the absence of coordination between different projects between the Ministry of Finance (funding organisation) and the ministries responsible for the implementation of these projects. The poor coordination resulted in severe financial damage, because many projects were commenced without budget consideration. According to an interviewed academic participant:

“I believe the main challenge that the government faced when planning and implementing public projects was that they considered only the cost of the project itself without looking at other direct or indirect elements that could affect the project—eg, the maintenance and operation of the projects” (IA6, 2015).⁵⁶⁶

⁵⁶⁴ Interview with an official, Secretary General of the Research Council.

⁵⁶⁵ Interview with Oil Company, Retired Director from Petroleum Development Oman (PDO)

⁵⁶⁶ Interview with Sultan Qaboos University (SQU), Associate Professor at SQU: Department of Electrical and Computer Engineering

One of the objectives of the Development Council in 1974 was to perform a detailed appraisal of all active projects and maintain their budgetary implications.⁵⁶⁷ Additionally, the increase in oil price has inhibited the productivity of other sectors such as agriculture and manufacturing, which could not accomplish their goals of contribution to national GDP. This is a common phenomenon known as Dutch disease, in which investment in one sector leads to neglect of other sectors. For example, the first plan set out to achieve by 1980 a contribution to GDP of 3.7% by agriculture, but the actual contribution was 2.5%. Similarly, the manufacturing sector contributed 0.8% in 1980, despite the plan target of 3.1%.⁵⁶⁸ Furthermore, the literature regarding the effects of resource curse on the different sectors of the Omani economy can be noticed in the sectorial government investments, which is carried out in most of all development plans. The focus of the investments in the development of the resource sector (energy sector) is evident. For example, the Gross Fixed Capital Formation for the oil and gas sector represents 42% of the total Gross Fixed Capital⁵⁶⁹.

The process of development required an increasing reliance on purchase of abroad services as well as immigrant workers. For example, the target plans for expenditures for these was OMR 102 million, but the actual payments were OMR 212 million. This overshoot was largely due to a larger than anticipated rise in the number of workers from abroad, both in the private sector, in which the number of non-Omani workers doubled, and the civil services, in which the number almost quadrupled.⁵⁷⁰ In other words, the increase in public actual expenditure exceeded the planned target level, mainly because of the many developmental projects made without reference to a wider framework of the economy.

Second 5-year development plan (1981–85): The main objectives of the second 5-year plan were to develop infrastructure, modernise the economy, and strengthen the private sector. These objectives were inspired by a number of factors, including the ability to make use of the newly discovered oil reserves and the increase in oil prices during the late of 1970s. The consequent rise in oil revenues allowed the Omani government to invest more in development of the country in general and expansion of government institutions. Because of the expansion

⁵⁶⁷ MOCI (1976) Commercial Business Laws of Oman. Muscat: Ministry of Commerce and Industry.

⁵⁶⁸ al-Yūsuf, M.I.M., 1995. *Oil and the Transformation of Oman: 1970-1995; the Socio-economic Impact*. Stacey Internat.

⁵⁶⁹ NCSI (2016) Statistical yearbook. Muscat: National Centre for Statistics and Information

⁵⁷⁰ NCSI (1986) Statistical yearbook. Muscat: National Centre for Statistics and Information.

of transportation and ports during the first 5-year plan, it was necessary to improve the capacity of the economy to make use of innovation from abroad,⁵⁷¹ and the domestic market witnessed a growth in many sectors as well as an increase in competition.⁵⁷²

However, during the years of the second 5-year plan, many of the development target plans could not be achieved, mainly because of a sharp decline in oil prices in the global market, which started in 1982. An interviewed government official expressed some problems that Oman faces when oil prices fluctuate:

“The Ministry of Finance always projects an estimated state general budget for the year to come, based on an estimated oil price per barrel at the end of each year. The policy makers are always cautious when planning the predicted revenues as well as the expenditure. Regardless, many times the budgets have experienced a deficit, like now. I think this is due to poor planning, and the absence of appropriate regulation to control state spending” (IO10, 2015).⁵⁷³

In addition, the literature on the resource curse symptoms can be witnessed in the inefficient use of resource revenues due to the fact that some externalities such as oil price fluctuations could not be totally avoided. According to Paul et al. some of the fluctuations in resource revenues are largely predictable due to geology and depletion of resources, however it is important to structure investment processes to be able to manage efficiently with substantial fluctuations.⁵⁷⁴

Another government official participant explains that the production level of oil and gas is difficult to predict:

“Unlike our neighbouring countries, Oman’s geological formation is complex, which makes the extraction of oil and gas very hard. So, the accessibility and productivity of oil and natural gas are difficult to predict.

⁵⁷¹ The implementation of these development plans initially required a massive and skilled labour force which was absent domestically, and since then the demand for labour has been growing rapidly.

⁵⁷² Maddy-weitzman, B. ed., 1997. *Middle East Contemporary Survey: Volume Xix, 1995* (Vol. 19). The Moshe Dayan Center.

⁵⁷³ Interview with an official, Assistant Secretary General for Programs and Research, the Research Council

⁵⁷⁴ Collier, P., Van Der Ploeg, R., Spence, M. and Venables, A.J., 2010. Managing resource revenues in developing economies. *IMF Staff Papers*, 57(1), pp.84-118.

Thus, policy planners commonly do not achieve the projected target” (IO16, 2015).⁵⁷⁵

The target growth rate of the oil and gas sector was set at 13% per annum in the second 5-year plan, but the actual rate was 5.5% as a result of low oil prices during this time (table 6-1).

Table 6- 1: Annual growth rate of different sectors of the economy: target versus actual, 1976–95

	First plan (1976–80)	Second plan (1981–85)	Third plan (1986–90)	Fourth plan (1991–95)
Nominal GDP at market price				
Target	2.2%	13.1%	-2.4%	6.3%
Actual	23.3%	10.9%	3.4%	2.8%
Oil and gas sector				
Target	-1.3%	13.0%	-6.3%	5.0%
Actual	21.3%	5.5%	4.2%	-2.8%
Non-oil activities—value added				
Target	8.1%	13.4%	0.7%	7.3%
Actual	27.0%	17.8%	2.7%	7.4%
Manufacturing				
Target	64.1%	34.2%	15.2%	12.7%
Actual	49.3%	39.5%	12.9%	11.8%
Other industrial activities*				
Target	-2.2%	12.5%	-6.8%	12.1%
Actual	13.2%	16.4%	-8.0%	6.0%
Agriculture and fisheries				
Target	8.2%	15.6%	3.3%	7.6%
Actual	21.1%	12.2%	6.3%	5.9%
Services				
Target	10.1%	12.2%	0.2%	6.0%
Actual	32.5%	17.7%	3.5%	7.2%
Public†				
Target	13.5%	11.0%	0.1%	3.5%
Actual	29.7%	19.7%	6.6%	4.4%
Private				
Target	7.9%	13.1%	0.3%	7.7%
Actual	34.0%	16.7%	1.6%	9.1%
Industry‡				
Target	-0.6%	13.3%	-4.6%	6.4%
Actual	20.6%	7.4%	3.2%	0.8%

⁵⁷⁵ Interview with an official, Minister of oil and Gas

Source: compiled by the author with data obtained from NCSI, (2012)⁵⁷⁶

*Electricity and water, mining, quarrying, and construction. †Producers of government services. ‡Petroleum activities, manufacturing, and other industrial activities.

By contrast, the non-oil sector witnessed an increase of 17.8% in its annual growth rate, which was much higher than the planned rate of 13.4% (table A). Similarly, all other non-oil sectors except agriculture and fisheries witnessed an above-target increase in the annual growth rate. These perceived increases are largely due to the oil activities in the Omani economy; because of the decrease in the oil sector, the value-added share of the non-oil activities increased, which did not reflect real-terms increases in productivity. For example, the manufacturing sector increased its contribution to GDP by 39.5%, mainly because of the opening of new manufacturing sites, including a cement company, oil refinery, copper mine, and flour mill. However, this percentage would be much lower if oil had not decreased its percentage contribution, thus leaving the non-oil sector as a greater proportion of the contribution.

The policies implemented during the second 5-year development plan allowed unrestricted imports of services and goods such as foreign labour, which led to adverse effects in the Omani economy. For example, the proportion of gross domestic savings that moved out of the country increased, because of payments to expatriate workers, contractors, and non-Omani partners of oil companies, equalling OMR 137 million in 1980 and OMR 327 million in 1985.⁵⁷⁷ In other words, the gross domestic saving leakage is more than 10% of GDP, and these remittances not only substantially decrease the external account surplus but also expand the gap between domestic investment and gross national savings. The problem of retaining GDP domestically has been increasing ever since. In 2013, Sultan Qaboos delivered a speech in which he stated that:

*“Remittances that come out of the country are more than the known official income, and are estimated at billions of Omani rials each year. This is because it is a hidden trade and this hidden trade damages the economy of Oman and reduces the opportunities available to Omanis to find jobs and this is unacceptable”.*⁵⁷⁸

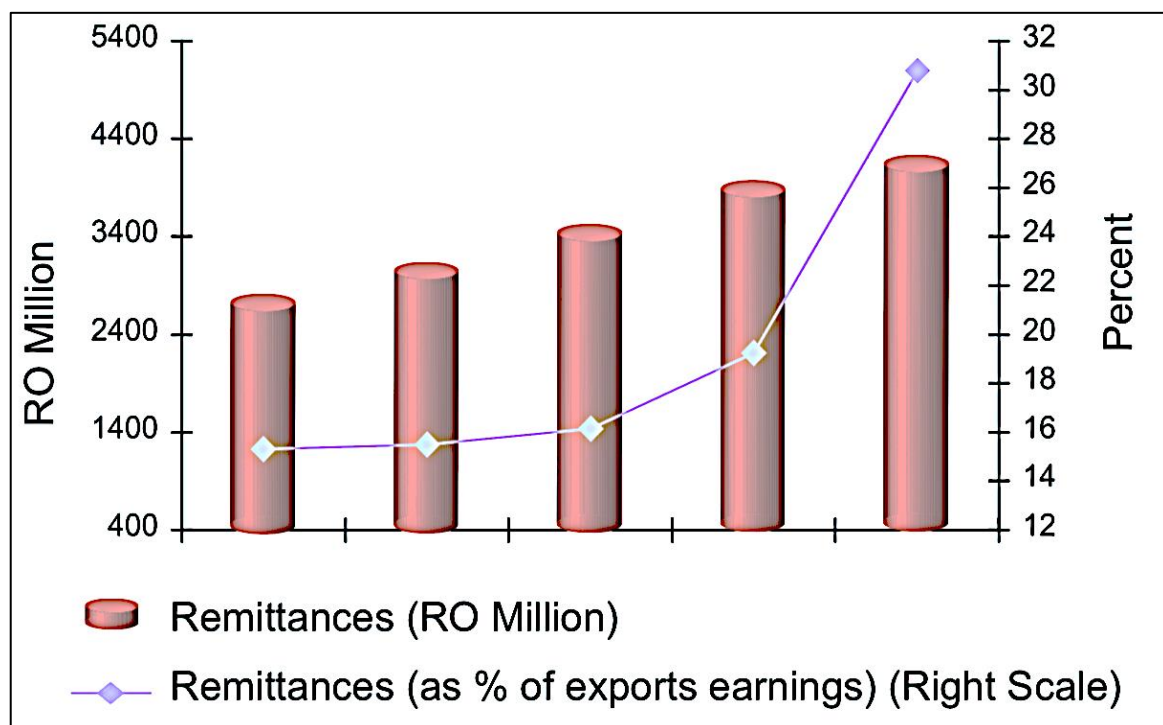
⁵⁷⁶ NCSI (2012) Statistical yearbook. Muscat: National Centre for Statistics and Information.

⁵⁷⁷ al-Yūsuf, M.I.M., 1995. *Oil and the Transformation of Oman: 1970-1995; the Socio-economic Impact*. Stacey Internat.

⁵⁷⁸ In 2013, His Majesty Sultan Qaboos bin Said delivered a speech to the sheikhs of the inner and central governor of Siaheh Shamkhat in the province of Bahla. Retrieved from website: <https://www.youtube.com/watch?v=UpF8HWvd5bU>

The monetary transfers associated with external worker remittances increased significantly to reach OMR 4,226 million in 2015 (Figure 6-2). According to Brahim, there is a direct relationship between the foreign worker's remittances outflow and resource curse phenomena on the GCC economies. This is because the GCC countries are relatively small population size and rely massively on oil resources, which have lead them to depend significantly on foreign workers. In other words, the more stock of migrants in GCC countries the higher outflow remittances is expected. In addition, Brahim also argued that foreign workers' remittances contribute massively to decreasing the appreciation of the real exchange rate in the host counties (GCC countries) of foreign labour.⁵⁷⁹

Figure 6- 2: Transfer associated with outward remittances, 2011–15



Source: Central Bank of Oman, Annual report (2015)⁵⁸⁰

Accordingly, in 2011, the World Bank ranked Oman internationally as one of the top remittance-sending countries,⁵⁸¹ because expatriate labour wages are often higher than those in

⁵⁷⁹ Razgallah, B., 2008, January. The macroeconomics of workers' remittances in GCC countries. In *Economic Research Forum, Working Paper* (Vol. 410).

⁵⁸⁰ CBO (2015) Annual report. Muscat: Central Bank of Oman.

⁵⁸¹ Ennis, C.A. and Ra'id, Z., 2014. *Elusive Employment: Development Planning and Labour Market Trends in Oman*. Chatham House, The Royal Institute of International Affairs.

their home countries, and the value of the Omani rial is higher than the currency in most expatriate workers' home countries. An interviewed academic participant adds:

“The absence of appropriate planning created another issue in the domestic market. The highly skilled and comparatively low-cost expatriate labour force created unbalanced competition for Omanis who could not accept the same level of salary” (IA18, 2015).⁵⁸²

The poor foresight during the second 5-year development plan had caused a huge increase in fiscal deficit, a decrease in gross national savings, and a decline in the current account surplus. Literature on the planning process stresses the important role of local capacity in the successful introduction, adoption, and implementation of many planning-related efforts such as technical skills from planners and fund allocation, which are essential to prepare high-quality plans.⁵⁸³ According to the British National Planning Policy Framework, the main purpose of any planning systems is to contribute to the achievement of sustainable development through building strong and competitive economy, vibrant and healthy social communities, and protecting and enhancing the environment.⁵⁸⁴

Thus, the crisis in the planning process during the second 5-year development plan was largely related to the insufficient or absent planning institutions and procedures. For example, three expensive projects either surpassed the planned costs or were unplanned at the commencing of the second plan. First, the Al Bustan Hotel was not planned within the budget, and cost OMR 80.4 million. Second, a university was built but not planned for in the budget, which cost OMR 114.8 million. Third, the Diwan of Royal Court Affairs was planned to cost OMR 40 million but greatly exceeded this estimate, costing OMR 220.6 million.⁵⁸⁵ The Omani government largely managed to overcome the issues of large unplanned fiscal deficit through the State General Reserve Fund (SGRF), which was established within the planning framework.

⁵⁸² Interview with an academic, Sultan Qaboos University, Professor at Department of Electrical and Computer Engineering

⁵⁸³ Conroy, M.M. and Berke, P.R., 2004. What makes a good sustainable development plan? An analysis of factors that influence principles of sustainable development. *Environment and planning A*, 36(8), pp.1381-1396.

⁵⁸⁴ National Planning Policy Framework. (2012). Achieving sustainable development - National Planning Policy Framework - Guidance - GOV.UK. [online] Available at: <https://www.gov.uk/guidance/national-planning-policy-framework/achieving-sustainable-development> [Accessed 9 Sep. 2018].

⁵⁸⁵ Ibid

However, the SGRF cannot sustain a high level of deficit for long without establishing credit rating problems, which is now becoming evident after the oil shock affecting many oil-exporting countries.

Third 5-year development plan (1986–90): The third 5-year development plan coincided with a continuation of the decline in oil prices in the global market from US\$27 per barrel to \$13 per barrel in 1986. Despite oil production increasing by 11% and other non-oil revenues also increasing, total revenues declined by about a third, from OMR 1,510 million to 929 million.⁵⁸⁶ This decline in revenues created such a great pressure on the government policy planners to create a balanced trade-off between completing the many ongoing projects that were initiated during the second 5-year development plan and maintaining the existing assets in a situation of limited financial resources. The government focused on maintaining assets by attempting to increase oil production gradually to offset the cost of ongoing projects. However, after 1986, oil declined to \$8 per barrel, despite an anticipated increase to \$24 per barrel.⁵⁸⁷ This price would halve oil revenues.

Government policy planners adopted a course of policy measures at the beginning of the third 5-year development plan in order to minimise the adverse effects of the oil crisis on the Omani economy. These policy measures included the reformulation of the third 5-year development plan in accordance with the marked recession in the oil market, decreasing the amount allocated to the SGRF from 15% of oil revenues to 5%; devaluation of the Omani rial by 10% against the US dollar (from US\$2.89 to 2.60), and reducing all public expenditure by 11% without reducing expenditure on health, education, and social affairs, which could cause social hardship. Thus, the fiscal deficit increased from OMR 596 million to 1,673 million, an increase of 180%. The final measure stresses the importance of Omani policy planners' commitment to social welfare. In addition to these policy adjustments, measures were also included to increase private sector activities and to privatise some government assets, especially in the electricity sector.⁵⁸⁸

⁵⁸⁶ The Third Five-Year Development Plan (1986-90):1986, Development Council of Sultanate of Oman.

⁵⁸⁷ Ibid

⁵⁸⁸ Ibid

Overall, the results of the third 5-year development plan confirm that the policy measures adopted at the beginning of the oil crisis were quite successful. They allowed Oman to overcome the shock of low oil prices without losing track of development and without reducing investments in social services. Although the success outcomes during this third plan were mainly due to the rapid adaption of policies to the new circumstances, the flexibility of planning as a technique proved the soundness of achieving economic development in an oil-based economy such as Oman.

However, public expenditure was not sufficiently controlled during the third plan. For example, the adjusted plan target for development expenditure was OMR 1,932 million, but the actual value was 1,719 million (table 6-2). The actual current expenditure of OMR 6,726 million was higher than the planned target of 6,055 million. Furthermore, the current expenditure in the third 5-year development plan increased by about 20% from the preceding plan. This indicates that overspending in current expenditure has been a consistent factor of the Omani policy planners budgetary mismanagement. In other words, mismanagement of resource's revenues and the high level of public expenditure is perceived as the effects of the resource curse symptoms.⁵⁸⁹

Table 6- 2: Public finance indicators—revenues, expenditure, and deficit: target versus actual, 1976–95

	First plan (1976-80)	Second plan (1981-85)	Third plan (1986-90)	Fourth plan (1991-95)	Cumulative (1976-1995)
Total revenues					
Target	2,393	6,947	6,491	8,571	24,402
Actual	3,116	6,605	7,098	8,598	25,417
Gross oil revenues					
Target	2,236	7,501	5,045	8,156	22,938
Actual	3,125	6,649	6,016	7,282	23,072
Transfer to reserves					
Target	-	1,125	-	1,570	2,695
Actual	274	920	405	770	2,378
Net oil revenues:					
Target	2,236	6,376	5,045	6,586	20,243
Actual	2,851	5,729	5,611	6,503	20,694
Other revenues					
Target	157	571	1,446	1,985	4,159
Actual	265	876	1,487	2,095	4,723
Total expenditure*					

⁵⁸⁹ Springborg, R., 2013. GCC Countries as "Rentier States" Revisited.

Target	2,631	7,368	8,164	9,450	27,613
Actual	3,340	7,872	8,616	10,953	30,781
Current expenditure					
Target	1,820	5,138	6,055	7,214	20,227
Actual	2,348	5,518	6,726	8,674	23,266
Civil					
Target	774	2,026	2,890	3,778	9,468
Actual	824	2,132	3,125	4,475	10,556
Development					
Target	811	1,961	1,932	2,107	6,811
Actual	903	2,088	1,719	2,148	6,858
Oil					
Target	88	544	578	761	1,971
Actual	205	456	561	739	1,961
Support to private sector					
Target	-	269	179	129	577
Actual	89	266	171	131	657
Surplus (+) or deficit (-)					
Target	-238	-421	-1,673	-879	-3,211
Actual	-224	-1,267	-1,518	-2,355	-5,364
Net deficit					
Target	-122	-384	-1,673	-879	-3,058
Actual	-9	-1,088	-1,515	-2,334	-4,946

Source: Mohamed AL Yousef, (1997)⁵⁹⁰

Data are OMR (millions). *Total expenditure is current expenditure plus investment.

Fourth 5-year development plan (1991–95): The fourth 5-year development plan was the final developmental plan of the short-term development strategy (1976–95). The main objective of this fourth plan was to diversify the sources of national income through directing more investments into the private sector and accelerating development of Omani human resources to reduce the rate of immigration to Oman, and reducing the heavy dependence on the oil sector.⁵⁹¹ By 1990, social and economic infrastructure, including health and education services and links between the oil and private sectors, were already established. Therefore, the fourth plan was framed on the basis of the development already achieved. Additionally, the political situation of the Gulf War resulted in a significant rise in oil prices in the global market (Iraq's

⁵⁹⁰ Al-Yousef, M.B.M., 1997. *The state and market in Oman's development: conflict or cooperation?* (Doctoral dissertation, University of London).

⁵⁹¹ World Business and Investment Library. (2016). [online] Available at: <https://www.amazon.com/Oman-Criminal-Regulations-Procedures-Handbook/dp/1514507757> [Accessed 6 Sep. 2018].

invasion of Kuwait in 1990 increased oil prices from US\$16 to 40 per barrel), increasing optimism among Omani policy planners in their predictions of oil price trends during this period.⁵⁹²

The policy planners identified some areas in which efforts needed to be focused as follows:⁵⁹³

- Expanding the foundation of the Omani economy and enhancing the non-oil sector
- Diversifying away from the dependency on oil revenues and improving the mechanism for controlling oil price fluctuation
- Strengthening the role of the private sector
- Preserving and sustaining natural resources
- Managing public current expenditure and balancing between government spending and revenues.

The target of the fourth 5-year development plan was to increase investments expenditure by 42% from the previous 5-year plan results. The target for average annual growth rate of GDP was set at 6.3% (table A). The non-oil sector had a target of an average annual increase of 7.3% and the contribution of the oil sector was planned to increase by 5.0%. Therefore, the share of oil sector in GDP was planned to decrease to 42% by the end of the fourth plan, from 50% in 1990; the share of the non-oil sector was planned to increase to 58% by 1995, from 50% in 1990.⁵⁹⁴ These were optimistic targets planned to achieve an increase in GDP, and the major elements were challenging. Challenges arose largely because of an absence of technical expertise both at the level of operating ministries and departments as well as at the level of technical secretariat.⁵⁹⁵

In addition to special emphasis on economic diversification, the agriculture and fisheries and manufacturing sectors were targeted to increase at an average annual rate of 7.6% and 12.7%, respectively (table A), and the planned rate for the services sector was 6.0%. However, these

⁵⁹² The Fourth Five-Year Development Plan (1991-95):1991, Development Council of Oman. Commercial business laws of Oman, publish by the Ministry of Commerce and Industry.

⁵⁹³ al-Yūsuf, M.I.M., 1995. *Oil and the Transformation of Oman: 1970-1995; the Socio-economic Impact*. Stacey Internat..

⁵⁹⁴ Al-Yousef, M.B.M., 1997. *The state and market in Oman's development: conflict or cooperation?* (Doctoral dissertation, University of London).

⁵⁹⁵ The Fourth Five-Year Development Plan (1991-95):1991, Development Council of Oman. Commercial business laws of Oman, publish by the Ministry of Commerce and Industry.

targets were mostly not achieved. Thus, Omani policy planners introduced a set of measures in an attempt to strengthen the institutional mechanism to manage volatility in global oil prices. The most important measure was increasing payments to the SGRF from 5% to 15% of GDP. Also, establishing a contingency reserve fund to which whenever oil prices exceeded a specified threshold, a transfer of a specified amount of net oil revenues should be made.⁵⁹⁶ After completing the first year of the fourth 5-year plan in 1991, a decline in oil prices as a result of the restoration of the Al Sabah monarchy in Kuwait and the removal of Iraqi forces by an allied coalition, which stabilised the global oil market's uncertainty and oil disruptions, led to problems in Oman.⁵⁹⁷ Oil prices reduced to US\$16.5 per barrel, which was about 18% lower than the \$20 per barrel on which the fourth plan was based. This resulted in a decrease in national revenues in Oman of about OMR 300 million between 1990 and 1991.

Another issued accord in the gross national savings (GNS) of the economy. Towards the end of the fourth plan (1995), domestic savings accounted for 26% of GDP, compared with the 34% accomplished at the end of the previous plan in 1990. This was mainly because of the decrease in both public and private savings, which was largely caused by the unmanaged growth of consumption expenditure (ie, total government and non-government expenditure). For 1995, the plan had predicted a target of 67% for consumption expenditure, but the actual value was 74%, while public sector consumption (ie, education, health, electricity production plants) was targeted at 25%, but reached 33%.

The Omani government is the main employer in the public sector, and 69% of Omanis work in the public sector. This high proportion of public sector jobs is potentially because of the feeling among Omani citizens of a right to a share of the country's wealth.

Although the fourth 5-year development plan improved the share of the non-oil sector in GDP from 50% in 1990 to 62% in 1995, it was unsuccessful in overcoming the key challenges of the national economy—the increasing fiscal deficit and decreasing savings ration. This is because Omani policy planners had no control over the global political economy of oil and its consequent influence of oil revenues; however, Omani policy planners did have the potential

⁵⁹⁶ The Library of Congress. (1994). Persian Gulf states : country studies. [online] Available at: https://www.loc.gov/resource/frdcstdy.persiangulfstate00metz_0/?st=gallery [Accessed 9 Sep. 2018].

⁵⁹⁷ Leigh, N.G. and Blakely, E.J., 2016. *Planning local economic development: Theory and practice*. SAGE publications.

ability to limit the expansion of public expenditure and prevent the decrease in the national economy savings. Leigh and Blakely argued that the problems arising in planning were not due to technical skills and employees, but rather the type and extent of policy making.⁵⁹⁸

The role of policy planning in Oman's development processes has been vital, as shown by this research, but it remains that the most important factor in sustaining development in Oman has been a depleting natural resource, oil and natural gas revenue, which many developing countries do not possess. Despite the fact that oil and natural gas are valuable resources, they will be exhausted in the near future, and their price fluctuates rapidly causing instability for Oman's economy. According to the literature, a decline in oil extraction rate would lead to a shortage in supply and ultimately growing oil prices. Therefore, passing the oil peak point could be, as campbell described, the "end of cheap oil".⁵⁹⁹

Thus, good planning policies and institutional arrangements need to deal with Oman's situation in a way that could mitigate risks associated with the collapse of oil prices, reducing negative social and economic implications, and making good use of oil resources. Additionally, the variability and instability of the economy and development of different sectors cannot be solely justified by fluctuations in the oil price or its production quantities. Government intervention is vital in these aspects, and can be arranged through proper policies and planning.

6.2.2 Vision 2020

Oman underwent remarkable socioeconomic development between 1976 and 1995. However, a number of serious obstacles still had to be overcome to achieve more sustainable development. One was the high probability of oil depletion within the next two decades (mentioned in the literature, section 2.2.1). Furthermore, the Omani population was growing quickly and half of the population were younger than 20 years.⁶⁰⁰ This put the Omani government under great pressure and led the government to adopt a new policy of

⁵⁹⁸ NCSI (2012) Statistical yearbook. Muscat: National Centre for Statistics and Information.

⁵⁹⁹ Campbell, C.J. and Laherrère, J.H., 1998. The end of cheap oil. *Scientific American*, 278(3), pp.78-83.

⁶⁰⁰ MONE (1996) Fifth Five-Year Plan 1996-2000. Muscat: Ministry of National Economy.

diversification, based on the necessity of minimising reliance on oil revenues and at the same time maximising employment opportunities for the Omani population.⁶⁰¹

In 1995, the Omani government hosted a conference to draw up a future plan for national economic and social development: Vision 2020. This meeting occurred at a time when oil prices had been gradually declining for almost 15 years. The conference findings reported that “the world we are living in is changing very fast and the acquisition of global knowledge, information and technology, and development of advanced human skills are essential tools for progress”.⁶⁰² Therefore, Vision 2020 stresses the great importance of diversifying the economy away from oil, human resources development, and private sector improvement.

In 1996, the Omani government activated Vision 2020. The plan mainly aims to gradually transform the country from having an oil-based economy to a non-oil-based economy, by depending more on private initiatives and national labour. The government intended to use the resources generated from oil and gas revenues to support the national economic diversification strategy. The second aim of Vision 2020 was to maintain the per capita income at its current level and strive to double it in real terms by the year 2020. Vision 2020 also included the training skill development of the Omani people.⁶⁰³

By 2020, the Omani economy aims to have been transformed to a non-oil economy no longer depending on oil revenues. The contribution of the oil sector to the real GDP is projected to drop to 9% from 42% in 2010, the gas sector will contribute about 10%, up from about 3% in 2010, and the non-oil sector will increase from 55% in 2010, to 81% (Figure 6-3).⁶⁰⁴

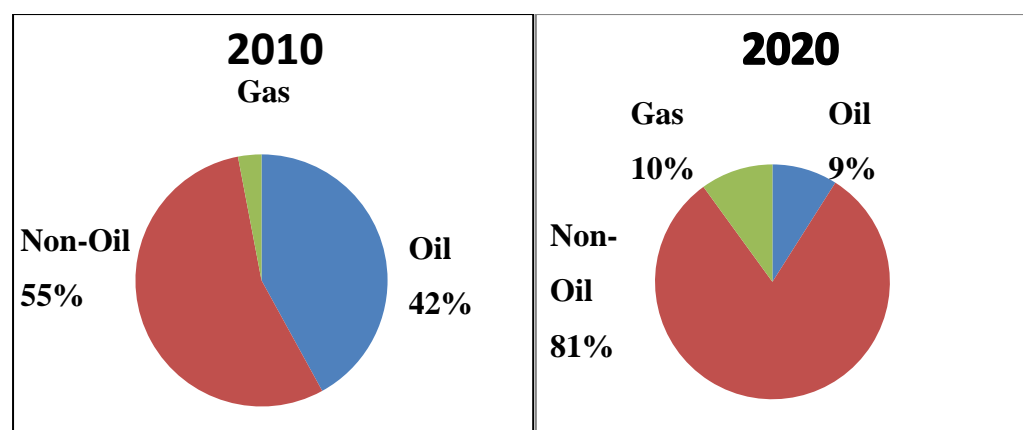
⁶⁰¹ Al Nabhani, M., 2007. *Developing the education system in the Sultanate of Oman through implementing total quality management-the Ministry of Education Central headquarters-a case study* (Doctoral dissertation, University of Glasgow).

⁶⁰² MONE (2000) Facts and Figures. Muscat: Ministry of National Economy.

⁶⁰³ NCSI (2012) Statistical yearbook. Muscat: National Centre for Statistics and Information

⁶⁰⁴ MANSOUR, A., 2013. Planning for Economic diversification in Oman.

Figure 6- 3: Percentage share in GDP contribution of national economic activities, 2010 and 2020



Source: statistical year book (2012), national centre for statistics and information

However, as of 2010, the non-oil-sector had decreased to 52.9% instead of increasing as planned; the decrease has gradually occurred over the years since 1995.⁶⁰⁵ Therefore, it is questionable that the goal of an 81% contribution can be achieved by 2020.

The manufacturing sector has at least doubled over the past two decades. However, this expansion is due to increased manufacturing activities in the oil services of the energy sector. In other words, the increase in manufacturing activities has added value mainly to the oil sector instead of other sectors of the economy such as tourism and agriculture and fisheries.

In general, Vision 2020 focuses on achieving more sustainable development through six main policy areas: world class human capital, a stable macroeconomic framework, a competitive private sector, high standards of living for the Omani people, preserving the past 25 years' achievements, and economic diversification.⁶⁰⁶

Vision 2020 has economic diversification for the Omani economy as one of its core aims. It consists of a set of economic development plans, spanning 25 years from 1996 to 2020. The Omani government plans to achieve the objectives through developing the right atmosphere for the creation of economic diversification and supporting the establishment of best practices in the domestic competitive private sector.

⁶⁰⁵ Ibid

⁶⁰⁶ MONE (2008) The development experience and investment climate. Muscat: Ministry of National Economy.

However, one missing element in Vision 2020 is a specific energy strategy for diversification of resources to achieve sustainability. Expanding the domestic economy requires energy policy to be outlined in a clear action plan with proper indicators and a dynamic monitoring and evaluation system.⁶⁰⁷ According to United Nations and the International Atomic Energy Agency, achieving sustainability requires wise use of resources, technology, suitable economic incentives, and unified strategic policy planning at the local and national levels. It also requires regular monitoring of the impact of selected strategies and policies to ensure they align with the main objectives. Another important feature is the ability to measure the current level of development of a country, and monitor its progress towards sustainability.⁶⁰⁸ The Omani Vision 2020 does not have the proper mechanism to record the progress of implementation or to measure its success. According to some officials, previous developmental plans did not achieve their main goals because of duplication of efforts between projects in many socioeconomic sectors, with little connection and integration between them. For example, each ministry in Oman has its own objectives for achieving the goals of Vision 2020. However, no coherence or cooperation between projects exists, resulting in doubling of efforts and waste of money and time.

An integrated strategy between the various governmental bodies involved in similar tasks does not exist. One governmental official interviewee stated that:

“The Vision 2020 does not show the detailed action plans and steps needed for energy policy to provide suitable conditions for sustainability. First, policymakers, as stakeholders, need to understand their country’s current status in terms of energy sustainability, what should be improved and how improvements can be made successfully. Second, policymakers need to understand the implications of their selected energy policies in shaping development and the probability of making this development sustainable. Third, since there will be a trade-off between the positive and negative effects of different sources of energy, there should be a wise and stable choices to be made on policy” (IO13, 2015).⁶⁰⁹

⁶⁰⁷ Eurostat, L., 2008. Energy indicators for sustainable development: Guidelines and methodologies.

⁶⁰⁸ Ibid

⁶⁰⁹ Interview with an official, Secretary General of the Research Council

Regardless of its pitfalls, Vision 2020 aims to reduce the share of the oil sector in national GDP to 9% by year 2020, compensating by increasing the export of non-oil products.⁶¹⁰ In reality, no clear policy plan denotes how to get to the desired figures. Table 6-3 shows the pattern of structural changes throughout the 5-year development plans.

Table 6- 3: Pattern of structural changes throughout the 5-year development plans

	1976– 80	1981–85	1986–90	1991–95	1996– 2000	2001– 05	2006– 10	2010
Non-oil contribution to GDP	43.7%	48.9%	57.8%	62.4%	61.1%	58.1%	57. 3%	52.9%
Manufacturing contribution to GDP	0.7%	1.7%	3.2%	4.1%	4.5%	8.3%	10.4%	16.7%
Non-oil exports contribution to total exports	3.8%	7.3%	9.7%	19.4%	22.4%	19.1%	23.1%	26.8%
Non-oil revenues contribution to total revenues	7.8%	11.3%	17.9%	21.1%	24.5%	23.4%	23%	24%

Source: Ministry of National Economy of the Sultanate of Oman: 2008, the development experience and investment climate.

A gradual structural change has occurred in Oman's economy (table 6-3). However, these changes do not reflect a reality of a more diversified economy with less oil dependency. For example, the share of non-oil exports to total exports over the past 25 years increased only marginally from 19.4% to 26.8%, which is again comes from the exports of oil products.⁶¹¹ In this context, according to an Economic and Social Commission for Western Asia report, developing countries, of which Oman is considered one, are facing several challenges, which need to be combatted by policy makers to achieve sustainability. These challenges are as follows: the increasing demand for energy due to both rapid population and industrial growth;

⁶¹⁰ Gavedanfar, M. (2017). Oman: The Arab world's emerging economy. [online] Meepas.com. Available at: <http://www.meepas.com/Omanemergingeconomy.htm> [Accessed 9 Sep. 2018].

⁶¹¹ MONE (2008) The development experience and investment climate. Muscat: Ministry of National Economy.

the absence of integration of sustainable energy strategies into national development strategies, policies and objectives, which are needed to balance between socioeconomic development and energy efficiency and conservation; the government energy sector subsidies, which lead to economic losses and limit development opportunities; the need to introduce renewable energy resources particularly in remote areas as a tool for poverty eradication and equity of energy access; and insufficient fund allocation for technology transfer and local capacity building.

Moreover, the oil-producing companies that operate in Oman are not anticipating new oil discoveries. Therefore, the Omani government offers substantial incentives to international oil companies for the exploration of new oil fields. However, the government has announced that the proven crude oil reserves account for 5.5 billion barrels, and this number has not increased since 1995.⁶¹² Hence, unless new major discoveries are made, oil is projected to last less than 20 years from now, based on the current rate of extraction. Thus, the literature (see section 2.2.1) suggests that passing the oil peak point would lead to an unavoidable decline in availability of fossil fuels, which confirms that the need to effectively allocate the remaining time to the shift to more sustainable resource.

It is important to establish how energy sustainability might be understood and achieved in GCC countries. The Brundtland Report's definition of sustainable development is that it "meets the needs of the present without compromising the ability of future generations to meet their own needs".⁶¹³ This definition could be used in the context of GCC countries as the direct relationship between the energy consumed locally and the potential future energy that is exported, which their economies depend on.

The term sustainability is used frequently in GCC countries' strategies, visions, conferences, and initiatives. For example, Saudi Arabia has rebranded itself as "the Kingdom of Sustainable Energy" by setting a target to produce 50% of its total electricity from renewable energy by 2032.⁶¹⁴ Abu Dhabi introduced the Arabic term 'Estidama' for sustainability when developing its urban planning programme, which encompasses planning for the next generation and

⁶¹² MONE (2006) Annual report. Muscat: Ministry of National Economy.

⁶¹³ Keeble, B.R., 1988. The Brundtland report: 'Our common future'. *Medicine and War*, 4(1), pp.17-25.

⁶¹⁴ Kacare.gov.sa. (2017). The Vision: Energy Sustainability for Future Generations. [online] Available at: <https://www.kacare.gov.sa/en/FutureEnergy/Pages/vision.aspx> [Accessed 9 Sep. 2018].

improving quality of life for residents in four dimensions of sustainability, including economic, environmental, social, and cultural sustainability.⁶¹⁵ One of the common key objectives in the GCC energy sector is to reduce use of oil locally, so that more can be used for export, but each government might have different objectives for pursuing sustainability in its local energy policy.⁶¹⁶ For example, Kuwait was the first country in the GCC to adopt energy conservation measures for air conditioning of buildings through well defined building codes, which require walls and roofs to be well insulated against heat.⁶¹⁷ Qatar has shown interest in protecting the environment and reducing emissions, with the Qatar Petroleum Environment Fair, which has been implemented by both private and public sectors, with the purpose of preserving natural resources and safeguarding the environment for prosperity. The Qatar General Electricity and Water Corporation uses the Arabic term ‘Tarsheed’, which means both guidance and rationality, and aims to reduce per capita water and electricity consumption.⁶¹⁸ PDO uses the Arabic term ‘Miraah’, which means mirror, using concentrated solar power technology to harness light energy from the sun to sustainably produce steam for oil production purposes, with the objective of reducing the burning of natural gas, which can then be used for other local applications or for export.⁶¹⁹

However, in general, sustainability has gained more attention in the GCC when used in terms of economic and social sustainability, rather than environmental sustainability,⁶²⁰ which was inevitable since the GCC governments depend heavily on oil exports. The GCC government will continue to export oil in the international market at the expense of the environment. They will also continue to depend on natural gas for their electricity generation, and the concepts of energy sustainability are not incorporated in their energy systems, in terms of environmental friendliness of energy supply, social and cultural norms of the end-user, access to alternative

⁶¹⁵ Department of Urban Planning and Municipality. (2017). Estidama Abu Dhabi Urban Planning Council. [online] Available at: <https://www.upc.gov.ae/estidama> [Accessed 9 Sep. 2018].

⁶¹⁶ Lahn, G., Stevens, P. and Preston, F., 2013. *Saving oil and gas in the gulf*. Chatham House.

⁶¹⁷ Doukas, H., Patlitzianas, K.D., Kagiannas, A.G. and Psarras, J., 2006. Renewable energy sources and rationale use of energy development in the countries of GCC: Myth or reality?. *Renewable Energy*, 31(6), pp.755-770.

⁶¹⁸ Gulf Times. (2013). Qatar aiming for sustainable development goals. [online] Available at: <https://www.gulf-times.com/story/349825/Qatar-aiming-for-sustainable-development-goals> [Accessed 9 Sep. 2018].

⁶¹⁹ Glasspoint.com. (2017). Solar Thermal Power. [online] Available at: <https://www.glasspoint.com/miraah/> [Accessed 9 Sep. 2018].

⁶²⁰ OECD, 2007. Energy for Sustainable Development, OECD contribution to the United Nations Commission on Sustainable Development 15. doi:10.5363/tits.9.5_24

energy technologies, and most importantly, national sustainable energy development strategies, which were mandated for all countries around the world by the United Nations Conference on Environment and Development Agenda 21 in 1992 (Rio de Janeiro, Brazil, 3–14 June, 1992).⁶²¹

6.3 Conclusion

This chapter analyses the development planning policies in Oman that affect the energy sector in achieving energy sustainability. Through the analysis of respondents' statements in the semi structured interviews and secondary data, a serious problem clearly exists in relation to planning policies in Oman. Although the government has been implementing a series of socioeconomic development plans through the 5-year development plans as well as the Vision 2020, it has not successfully achieved its targets. Some of the challenges are related to the fluctuation of oil prices, which negatively affect the processes of planning policies and their implementation, whereas other problems have resulted from contradictions and challenges of Vision 2020. Furthermore, the oil and gas sector is still the greatest contributor to the Omani economy, in terms of budget revenues and exports, which clearly highlights the failure of planning policies to achieve a shift from an oil-based economy to a non-oil-based economy.

⁶²¹ OECD, 2007. Energy for Sustainable Development, OECD contribution to the United Nations Commission on Sustainable Development 15. doi:10.5363/tits.9.5_24

Chapter 7

Energy Diversification and Sustainability Policy

7.1 Introduction

This study analyses the factors behind the unsuccessful energy sustainability attempts in Oman using the sustainable development theory as a framework and concentrating on four categories of barriers: lack of energy policy, high domestic energy demand, poor diversification of energy resources, and insufficient environmental protection. Accordingly, this chapter offers the empirical findings that need to be addressed to achieve Oman's energy sustainability goals.

As mentioned in chapter four, Oman's economy is heavily reliant on the export of hydrocarbons. Because of depleting reserves and an expanding population, the Omani government has aggressively pursued a diversification plan that puts more emphasis on industrialisation and privatisation, with the aim of decreasing the contribution of the energy sector to GDP from the current level of approximately 45% to 9% by 2020.⁶²² This diversification plan focuses on developing more jobs for the increasing number of Omanis joining the country's workforce, as well as enhancing the tourism sector and gas-based industries.⁶²³ Oman has used enhanced oil recovery (EOR) techniques to increase its oil production, which, along with a rise in international oil prices, has allowed the country to increase revenues for the diversification programmes of its economy. The increased revenues have given the Omani government more options not only to invest in the non-hydrocarbon sector, but also to maintain growth in energy and social subsidies as well as public sector expansion.

Oil prices increased in 2011 and 2012 to more than US \$100 per barrel, exceeding government estimations. However, the Arab Spring also started in 2011, and the Omani government had to act immediately in response to the public unrest by increasing public expenditure on social welfare benefits and creating employment opportunities for thousands of Omanis, mostly in the public sector. This expenditure significantly delayed the government's goal of balancing its budget, which was further exacerbated by the sharp decline in oil prices globally in 2015. According to the World Bank, Oman's public expenditure system is not sustainable if oil prices

⁶²² In 2016, His Majesty Sultan Qaboos approved the Ninth Five-year development plan, which is the last plan of the Vision 2020. Scp.gov.om. (2017). Supreme Council for Planning. [online] Available at: <https://www.scp.gov.om/en/Page.aspx?l=15> [Accessed 10 Sep. 2018].

⁶²³ Gas can be used in a wide range of industrial applications such as steel, chemicals, fertilizer, enhanced oil recovery, power plants, and plastic production.

are less than \$100 per barrel, which has been the case since 2015. Furthermore, Sultan Qaboos bin Said al Said has stated clearly in official statements that the public sector will not be able to maintain its role as the main employer of young Omanis as the population increases, and that more efforts are needed to encourage private sector businesses. Thus, the private sector has a potential role to play in supporting and diversifying the national economy.⁶²⁴

The Ministry of Oil and Gas and the Ministry of Finance are responsible for the policies surrounding the energy sector in Oman, supported mainly by the Public Authority for Electricity and Water and Authority for Electricity Regulation (AER). The focal point of all international dialogue and issues regarding climate change is the Ministry of Environment and Climate Affairs.

However, one of the central barriers to sustainable domestic energy management is the absence of a coordinated energy policy operated by a single entity. This is the biggest challenge for policy making in the energy sector, because energy legislation is the responsibility of multiple ministries and authorities. Unification and simplification of these systems are vital to the economic diversification plans.⁶²⁵ Poor coordination of the supply and demand side of management could for example lead to the building of a new energy-intensive power plant without taking into consideration alternatives such as renewable technologies, rules and regulations, and efficiency measures. One government official agreed that a unified approach is needed:

The solution could be an independent entity with full authority to define the best energy mix for the energy sector as well as the power to establish a mandate for the conservation and efficient use of different types of energy. Also, this energy entity would require a holistic examination of all activities and stakeholders involved in the energy sector and a review of their long-term plans. In doing so, this energy entity could broadly merge plans that assist Oman's socioeconomic development with Vision 2020. It should act as the focal entity specifically for coordinating activities of ministries and government bodies (IO14, 2015).⁶²⁶

⁶²⁴ Worldbank.org. (2017). Mid-Term Review of the 8th Five Year Development Plan. [online] Available at: <http://www.worldbank.org/en/search?q=Mid-Term+Review+of+the+8th+Five+¤tTab=1> [Accessed 10 Sep. 2018].

⁶²⁵ Lahn, G., Stevens, P. and Preston, F., 2013. *Saving oil and gas in the gulf*. Chatham House.

⁶²⁶ Interview with an official, Minister of the Supreme Council for Planning.

Many government entities have fragmented plans that are mainly for closing the gap between energy consumption and production, which does not serve overall energy sustainability in the long run. In addition, the energy sector in Oman has no clear national energy policy or action plans in place. These plans are required to create a clear direction and trend for energy development in Oman, and to improve energy efficiency, diversify the energy mix, and integrate advanced energy technologies, which will in turn also lead to economic growth and job creation.⁶²⁷

However, formulating a realistic national energy plan requires the different energy authorities, especially those with the knowledge and capacity to enforce change, to communicate with each other on a range of energy-related issues. According to a government official interviewed by the Oman Observer Newspaper, policy formulation consists of two core aspects: policy formulation and execution. Creating a successful energy policy requires the involvement of lots of people who have a clear understanding of the process of both formulation and execution of policies, from various sectors in society, including academia and the private and public sectors. Most planners, however, tend to know a lot more about policy planning than putting the plan into action, leading to problems of implementation. The implementation process is delegated by the planners to other people who do not necessarily have the skills to implement the plans, without offering the necessary training or resources.⁶²⁸

Energy statistics are essential for designing strategies and policies, and reliable data is crucially important to assess energy sector performance. However, energy data in GCC countries, including Oman, are often disorganised and spread between various energy institutions, or simply not recorded or accessible. Furthermore, economic and commercial data might be kept confidential by the government because of non-transparency surrounding the dissemination of various energy-related statistics.⁶²⁹ Thus, overcoming this barrier is a key challenge. The government, however, can help members of the public who need data by providing political support, as implied by a government official interviewee:

⁶²⁷ Irena.org. (2014). Renewables Readiness Assessment: Sultanate of Oman. [online] Available at: <http://www.irena.org/publications/2014/Nov/Renewables-Readiness-Assessment-Sultanate-of-Oman> [Accessed 10 Sep. 2018].

⁶²⁸ Harthy, S. (2014). Strategy formulation vs its execution. [online] Oman Observer. Available at: <http://2015.omanobserver.om/strategy-formulation-vs-its-execution/> [Accessed 10 Sep. 2018].

⁶²⁹ Lahn, G., Stevens, P. and Preston, F., 2013. *Saving oil and gas in the gulf*. Chatham House.

If the government assigns new projects or research to an international energy agency, data and resources to carry out the required study will be provided [by the government to the agency], which might enhance the accuracy of information (IO4, 2015).⁶³⁰

However, obtaining support from the government generally requires solid economic justification. Institutions from the energy sector can justify their needs by giving an initial picture of energy and resource wastage using the scarce available data and then providing potential methods of energy saving in various areas such as refineries, the electricity sector, desalination, buildings, industry, and transport. Better data collection would result in better analyses by energy companies, which the government could use to develop a detailed sustainable national energy policy and increase public awareness of the need to change attitudes toward energy use. A world energy demand and economic outlook report from the US Energy Information Administration highlights the following five aspects that should be included in a sustainability policy:⁶³¹

1. Appliance efficiency standards
2. Transport fuel efficiency standards
3. Establishing standards for building codes and building materials
4. Reforming of tariffs and subsidies
5. Introducing new clean energy resources

However, in Oman, the culture of high energy consumption alongside population growth and economic development requires more severe policy interventions.

Other important factors in an energy system, besides social and political parameters⁶³², are the institutional indicators, which help assess the availability and capability of the institutional framework to encourage effective and efficient energy sustainability. Institutional indicators are useful for the development of policy responses to sustainable development requirements, to produce changes in the economy, environment, and culture. They also might help to assess the effectiveness and performance of a national energy strategy by monitoring progress towards

⁶³⁰ Interview with an official, Manager of Renewable Energy Research: The Research Council

⁶³¹ Eia.gov. (2017). Oman - International - Analysis - U.S. Energy Information Administration (EIA). [online] Available at: <https://www.eia.gov/beta/international/analysis.php?iso=OMN> [Accessed 6 Sep. 2018].

⁶³² Energy sustainability is not only impact on economic dimension but also on political and social dimensions.

suitable and effective regulatory, legislative, and enforcement measures for energy sustainability.⁶³³ According to an academic interviewee:

*The energy system in Oman does not have institutional indicators, but they could be adopted to help Oman achieve better energy sustainability (IA18, 2015).*⁶³⁴

However, institutional indicators are generally hard to define for two reasons. First, they tend to tackle issues that are difficult to assess with a quantitative approach, such as issues that are related to the future of energy in terms of active analysis of projections of energy supply, demand, and investment. Second, the energy sector is linked to other sectors such as the economic, social, and environmental sectors, so institutional measures should be assigned with all sectors in mind rather than independently for each sector⁶³⁵. Langlois and Rogner gave the following list of indicators for sustainable energy development:

- End-use energy prices with tax and subsidy
- Energy intensity: residential, industrial, transport, agriculture, and public services
- Energy supply efficiency: fossil fuels for electricity generation
- Status of deployment of pollution abatement technologies: extent of use and average performance
- Quantities of air pollutant emissions
- Energy security
- Diversification of energy mix

Growth in domestic oil and gas demand in Oman has led to an increase in energy unsustainability. The national resources of oil and natural gas are the only fuels that can meet the high energy demands, including those for electricity generation, transportation, industrial projects, desalination, and EOR for oilfields. In 2014, 77% of total natural gas production was used for domestic consumption, and 15% of oil consumption was domestic, with the remaining 85% used for export.⁶³⁶

⁶³³ Vera, I.A., Langlois, L.M., Rogner, H.H., Jalal, A.I. and Toth, F.L., 2005, November. Indicators for sustainable energy development: An initiative by the International Atomic Energy Agency. In *Natural Resources Forum* (Vol. 29, No. 4, pp. 274-283). Oxford, UK: Blackwell Publishing Ltd.

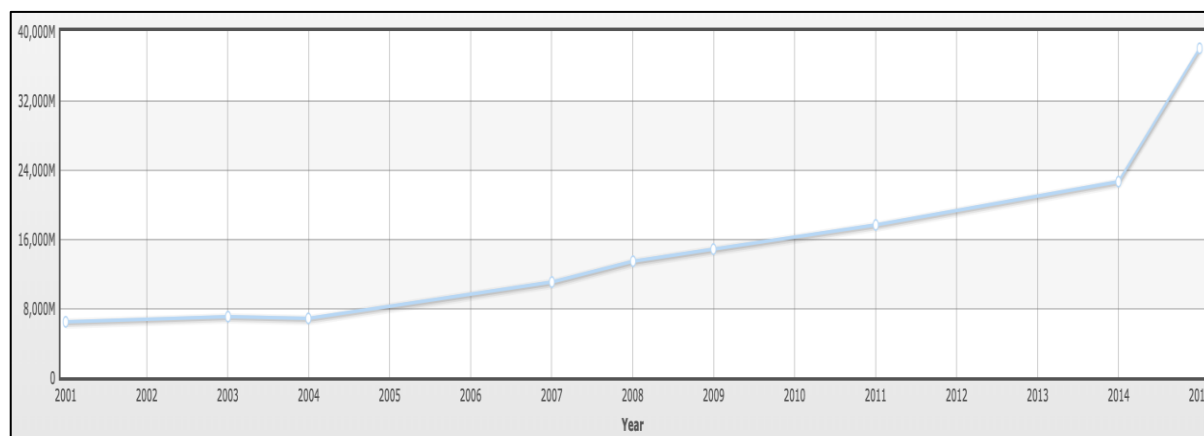
⁶³⁴ Interview with an academic, Sultan Qaboos University, Professor of Electrical and computer Engineering.

⁶³⁵ Vera, I. and Langlois, L., 2007. Energy indicators for sustainable development. *Energy*, 32(6), pp.875-882.

⁶³⁶ Oxford Business Group. (2016). The Report: Oman 2016. [online] Available at: <https://oxfordbusinessgroup.com/oman-2016> [Accessed 6 Sep. 2018].

Further pressure is put on the energy sector by continued population growth alongside economic diversification plans. Over four decades, natural gas domestic demand increased from 28 billion standard cubic feet (scf) in 1980 to 780 billion standard cubic feet in 2014, as depicted in Figure 7-1.

Figure 7- 1: Oman natural gas consumption (Cubic Feet), 2001-2015



Source: Compiled by the author from data obtained from NCSI (2016)

Similarly, the electricity sector, which delivers cooling, heating, lighting, and appliances for households and government, industrial, tourist, and agricultural and fishery sectors across the country, increased natural gas consumption from 236 billion scf in 2000 to 720 billion scf in 2014; a three-fold increase.⁶³⁷ According to the Undersecretary of the Ministry of Oil and Gas “There is a lot of demand for gas in the country. Industrial areas such as Duqm and Sohar are demanding more gas, as are a number of new industries that are up and coming”. He also highlighted that general economic development requires more natural gas than before by stating that “there is also an increase in power demand and power producers are asking for more gas. In the oil and gas industry, a fifth of gas resources are used in EOR projects for reinjection”.⁶³⁸ In 2014, 60% of total natural gas consumption was in industrial areas for projects such as oil refining, cement production, and other manufacturing, while 20% went toward electricity generation and water processing, and 20% was allocated to EOR.⁶³⁹

⁶³⁷ Eia.gov. (2017). Oman - International - Analysis - U.S. Energy Information Administration (EIA). [online] Available at: <https://www.eia.gov/beta/international/analysis.php?iso=OMN> [Accessed 6 Sep. 2018].

⁶³⁸ Ali Khan, G. (2014). Oman's natural gas consumption rises 3.2% in 2013,Oman. [online] Muscat Daily News. Available at: <https://www.muscatdaily.com/Archive/Business/Oman-s-natural-gas-consumption-rises-3.2-in-2013-2xx4> [Accessed 10 Sep. 2018].

⁶³⁹ NCSI (2015) Statistical yearbook. Muscat: National Centre for Statistics and Information.

Natural gas plays a dominant role in fuelling the electricity sector in Oman; 97.5% of electricity in Oman is generated from natural gas and the remaining 2.5% is generated from diesel (in off-grid rural areas).⁶⁴⁰ In addition to the high domestic demand for natural gas, Oman has many long-term export contracts, to which 44% of natural gas production is allocated each year. Oman imports small volumes of natural gas from Qatar to bridge the gap between electricity supply and demand, especially in the peak summer time.⁶⁴¹ Despite the government reform of the price of natural gas from US \$1.50 per British Thermal Unit (BTU) to US \$3.00 per BTU to encourage more conservative domestic use, this price remains much lower than the average international price of \$6.00 per BTU.⁶⁴² According to an interviewed Executive Director of the Authority for Electricity Regulation:

*The electricity prices remain low and consumers are not encouraged to use electricity efficiently, thus, this gas policy is not sustainable in the long term and must be revised (IEC23 2015).*⁶⁴³

The government also introduced new tariff structures to the electricity sector to raise electricity prices, but they are still low (table 7-1). The lowest tariffs in the winter are just OMR 0.012/kWh (US \$0.03/kWh).

Table 7- 1: Minimum energy tariffs set by the government for domestic and industrial use, 2016

	Off peak (0200–1259 h and 1700–2159 h)	Night peak (2200–0159 h)	Weekday day (Sun–Thurs, 1300–1659 h)	Weekend day (Fri–Sat 1300–1659 h)
January to March	12	12	12	12
April	14	14	14	14
May to July	17	26	67	39
August and September	15	21	26	19
October	14	14	14	14

⁶⁴⁰ AER (2015) Annual report. Muscat: The Authority for Electricity Regulation.

⁶⁴¹ Export.gov. (2017). Oman - Oil and Gas | export.gov. [online] Available at: <https://www.export.gov/article?id=Oman-Oil-and-Gas> [Accessed 10 Sep. 2018].

⁶⁴² Natural gas can be as expensive as US\$9 per BTU in the global market

⁶⁴³ Interview with Electricity Company, Executive Director of Authority for Electricity Regulation

November	and	12	12	12	12
December					

Data are baisa per kWh.

Source: Authority for Electricity Regulation, Cost Reflective Tariffs Report (2016)

Therefore, the overall structure of the fossil fuels, electricity, and water linkage systems in Oman is not sustainable; water and electricity demand are both increasing above the global rate, resulting in the reallocation of more hydrocarbons from export to domestic use every year.⁶⁴⁴

7.2 Energy policy

This section offers an analysis of respondents' opinions of the influence of energy policy for energy sustainability. As described, the importance of coherent and comprehensive energy policy is essential for the growth, prosperity, and social equity of any country. Reliability, affordability, availability, and accessibility to modern energy services are needed to achieve the desired sustainable development that confers a higher standard of living, including by providing health-care services, good-quality education, more economic opportunities such as jobs and projects, and better communication services, highlighted in the World Energy Insight 2010 report as “Energy services have a profound effect on productivity, health, education, safe water, and communication services. Therefore, it is no surprise that access to energy has a strong correlation to social and development indices (eg, Human Development Index, life expectancy at birth, infant mortality rate, and GDP per capita)”.⁶⁴⁵

However, in Oman, the existing energy policies have been made from fragmented bits of policy from the different sub-sectors (oil and gas, electricity, and raw materials). Some energy-related policies come from sub-sectors whose main activities are strongly dependent on the energy sector—eg, transportation, construction, and agriculture and fisheries. These sub-sectoral policies only reflect the individual sub-sectoral views without taking into account the wider issues. These problems show that an integrated and comprehensive energy policy is needed, which will also serve as a guideline for future energy-related sub-sectoral policy developments,

⁶⁴⁴ The electricity tariff structure has been the same since the 1980s, and electricity consumers pay less than 54% of costs in their bills.

⁶⁴⁵ Worldenergy.org. (2010). World Energy Insight 2010. [online] Available at: <https://www.worldenergy.org/publications/2010/world-energy-insight-2010/> [Accessed 10 Sep. 2018].

and hence prevent any future policy conflicts or redundant efforts. The importance of energy policy development has been stressed in most energy sustainability literature, because energy policies are the core components of any socioeconomic development (Hertog, 2009;⁶⁴⁶ Omer, 2008;⁶⁴⁷ Afgan, et, 1998;⁶⁴⁸ Peake, 2011⁶⁴⁹). Achieving sound sustainable energy development requires various policy interventions,⁶⁵⁰ including improving energy efficiency and conservation for buildings, appliances and equipment, and vehicles; reforming and reallocating energy subsidies; identifying the high potential of indigenous renewable energy resources and implementing policies to support their sustainable development; and preserving the environment by reducing greenhouse gas emissions from energy production, distribution, and use.

Policy makers in Oman have acknowledged the importance of putting energy policy development plans in place to use available alternative resources, protect the environment, and secure the welfare of present and future generations, as clearly stated in Sayyid Assaad Al-Said's speech, on behalf of His Majesty Sultan Qaboos, at the World Summit on Sustainable Development in Johannesburg, South Africa 2002:

*Remarkably, sustainable development is the backbone of the philosophy of Omani renaissance and development plans. It is an imperative dictated by the location of the Sultanate at the southern tip of the Arabian Peninsula, characterised by aridity, water scarcity, and sparse vegetation. Thus, more than ever before, Omani government has to find a means of striking a balance between the exploitation of available resources and the realization of national development plans on the one hand and maintaining a sound environment on the other.*⁶⁵¹

This statement clearly argues that there is a need for balancing the renewable and non-renewable natural resources in Oman, including the non-renewable oil and natural gas, and, the

⁶⁴⁶ Hertog, S. and Luciani, G., 2009. Energy and sustainability policies in the GCC.

⁶⁴⁷ Omer, A.M., 2008. Energy, environment and sustainable development. *Renewable and sustainable energy reviews*, 12(9), pp.2265-2300.

⁶⁴⁸ Afgan, N.H., Al Gobaisi, D., Carvalho, M.G. and Cumo, M., 1998. Sustainable energy development. *Renewable and sustainable energy reviews*, 2(3), pp.235-286.

⁶⁴⁹ Everett, R., Boyle, G., Peake, S. and Ramage, J., 2012. *Energy systems and sustainability: Power for a sustainable future*. Oxford University Press.

⁶⁵⁰ Ahuja, D. and Tatsutani, M., 2009. Sustainable energy for developing countries. *SAPI EN. S. Surveys and Perspectives Integrating Environment and Society*, (2.1).

⁶⁵¹ Summit, J., 2002. World summit on sustainable development. *Johannesburg, South Africa*.

renewable solar, wind, and nuclear energy, while avoiding pollution and other environmental hazards.

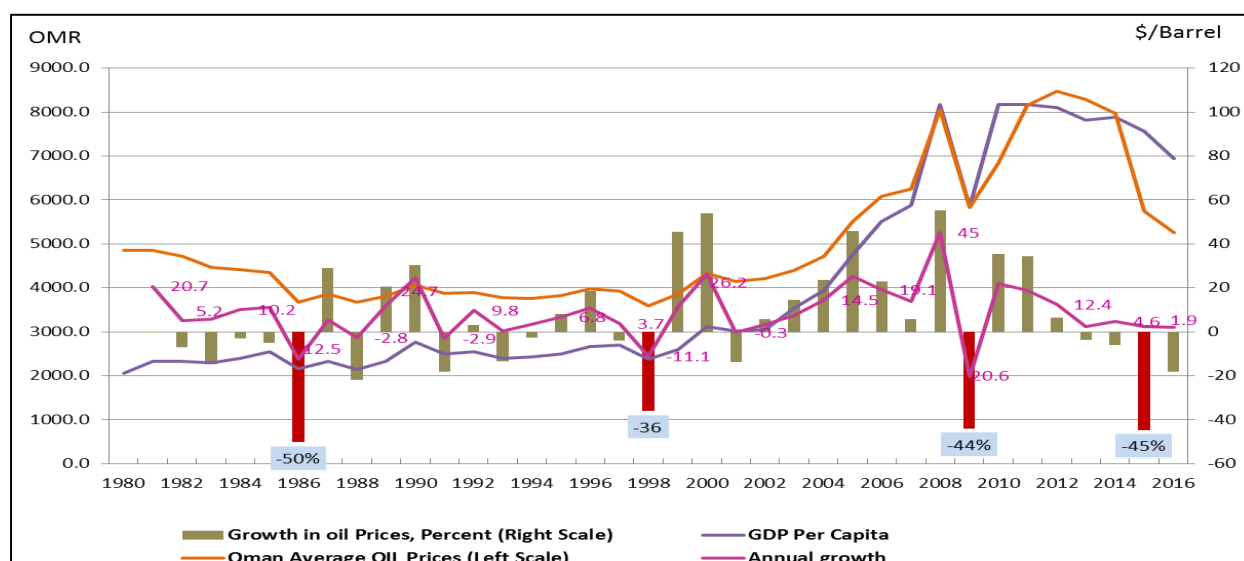
As discussed in chapter 4, many remarkable achievements have been made in implementing Oman's 5-year development plans and Vision 2020, especially for improving the general infrastructure, human resource development, and economic development. Some improvements made are the paving of roads, building of hospitals and schools, desalination of water, building of new power plants, and expansion of industrial areas. These developments have been accompanied by new laws, policies, and strategies to regulate all activities across the sectors in Oman.⁶⁵² However, the nature of developmental plans and strategies that have been implemented in the country depend heavily on its economic stability and the revenues from the export of oil and gas.⁶⁵³ The Omani government has been aware of the issue of economic dependence on hydrocarbons since the first shipment of oil and gas in 1967; and it is recognised that an economy relying heavily on the revenues of depleting energy resources is not sustainable. Because fluctuations in the international oil market are difficult to predict, plans and strategies made by policy makers were based on the "Planning under uncertainty" approach.⁶⁵⁴ Figure 7-2 illustrates the history of global oil price fluctuations and the oil shocks witnessed by oil-exporting countries, specifically Oman.

⁶⁵² Al-Ismaily, H.A. and Probert, S.D., 1997. Energy overview for the sultanate of Oman. *Applied energy*, 57(4), pp.287-325.

⁶⁵³ Lahn, G., Stevens, P. and Preston, F., 2013. *Saving oil and gas in the gulf*. Chatham House

⁶⁵⁴ Government of the Sultanate of Oman Supreme Council for Planning Muscat (2017). The Nine Five-Year Development Plan (2016-2020). Muscat: Supreme Council for Planning.

Figure 7- 2: Oil price fluctuations (the primary driver of the Omani economy), 1980-2016



Source: The ninth 5-Year Development Plan (2016-2020), Oman (2017)

Socioeconomic policies and strategies are more directed towards the economy sector than other sectors, with the aim of diversifying the income of the national economy sector, instead of depending on a sole source of energy (oil and gas). This has been clearly argued through all 5-year development plans since the original plan in 1976,⁶⁵⁵ and the final 5-Year Development Plan of Vision 2020 (2016-2020)⁶⁵⁶ focuses clearly on moving the national economy away from being hydrocarbon based by involving other sectors, such as agriculture, fisheries, industry, tourism, and the private sector. By implementing this ninth 5-year plan, the Omani economy could mitigate the repercussions of the external shocks from price instability in the international oil market. Specifically, the ninth 5-Year Development Plan aims to encourage the industrial, services, and domestic investment sectors to take the lead in driving the economy and reduce the contribution of oil and gas revenues from 66% of GDP in 2012 to 19% in 2020.⁶⁵⁷ However, the goal of 81% of GDP being generated by non-oil sectors by 2020 seems unlikely to be met, with privatisation plans improving much more slowly than domestic businesses had expected. However, the government has argued that privatisation is progressing at a rate suitable for Omani market conditions.

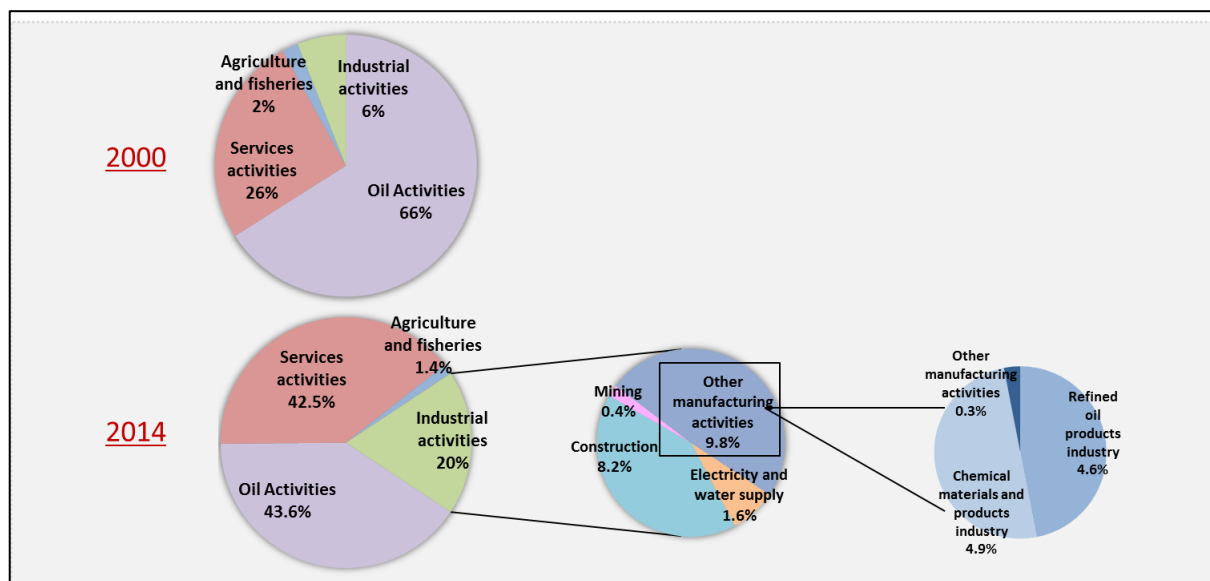
⁶⁵⁵ MONE (2004) Statistical yearbook. Muscat: Ministry of National Economy.

⁶⁵⁶ Government of the Sultanate of Oman Supreme Council for Planning Muscat (2017). The Nine Five-Year Development Plan (2016-2020). Muscat: Supreme Council for Planning.

⁶⁵⁷ NCSI (2012) Statistical yearbook. Muscat: National Centre for Statistics and Information.

The rapid fluctuation of oil prices in the global market reduces the accuracy of Omani economic indicators, because low oil prices lead to an increased proportion contribution of non-oil sectors, which can falsely indicate increases in productivity of these industries. An interview with the Omani Minister Responsible for Financial Affairs, H.E. Darwish Albalushi, said that the economic indicators of non-oil activities are linked directly to oil prices and change in response to oil price fluctuations.⁶⁵⁸ For example, if a barrel of oil is sold in the global market for \$100 and this share contributes to 70% of the Omani GDP, the share of non-oil sectors contributes to the GDP by the other 30%. However, if a barrel of oil is sold in the global market for \$50 and this share contributes to 35% of the Omani GDP, the non-oil sectors would have to double their revenues to contribute the other 65% of GDP. Indicators do not always reflect reality, because a decrease in an oil-activity indicator does not necessarily increase non-oil activity or vice-versa. Oil activities contributed 66% of the economy in 2000, which decreased to 44% in 2014. At the same time, non-oil activities contributed 34% to the economy in 2000 and increased to 66% in 2014, because of the fluctuation of oil price in the global market.

Figure 7- 3: The total share of economic activities in GDP (2000-2014)



Source: The ninth 5-Year Development Plan (2016-2020), Oman (2017)

One large gap in the results of Vision 2020 is the absence of appropriate indicators that reflect the reality of economic activities across all sectors, separate from the influence of oil prices.

⁶⁵⁸ Theworldfolio. (2012). Oman- a country on the rise and a country with a plan. [online] Available at: <http://www.theworldfolio.com/interviews/darwish-bin-ismail-al-balushi-minister-responsible-for-financial-affairs-oman-n1575/1575/> [Accessed 10 Sep. 2018].

This clearly highlights the pressing need for a detailed national energy policy that works in line with economic diversification strategies to achieve sustainable development.⁶⁵⁹

National energy policy is vital as a guideline and roadmap for countries to address issues of energy development such as energy production, distribution, and consumption to not only balance between energy supply and demand locally but also to enhance the growth of other sectors of the economy. National energy policy can be achieved through a country's implementation action plan that involves a set of appropriate measures such as legalisation, international agreements, subsidies, incentives to invest, energy efficiency and conservation, and environment protection for sustainable development.⁶⁶⁰

The participants in this study were asked to explore their views on the existence of a national energy policy in Oman⁶⁶¹. Although the question was unambiguous with little room for difference in interpretation, a wide range of responses were collected from interviewees. Interviewees were asked whether Oman has an overall national energy policy in place, and the majority of respondents stated that they did not believe so. For example, the minister of oil and gas said "there is no national energy policy (IO16 2015)".⁶⁶² Another respondent explained that there were lots of initiatives previously, but no national energy policy currently gathers all data on energy in Oman (IO4, 2015).⁶⁶³ However, even though the Omani government is aware of the pressing need for national energy policy to improve all sectors across the country, particularly the economic sector, the development of a centralised energy policy has not been completed. According to an interviewed government official, the need to develop national energy policy is essential to support the implementation of economic strategy and the development of the economic sector:

⁶⁵⁹ Callen, M.T., Cherif, R., Hasanov, F., Hegazy, M.A. and Khandelwal, P., 2014. *Economic diversification in the GCC: Past, present, and future*. International Monetary Fund.

⁶⁶⁰ International energy Agency (iea). (2014). Energy Policies of IEA Countries: The United States. [online] Available at: https://www.iea.org/publications/freepublications/publication/USA_2014.pdf [Accessed 10 Sep. 2018].

⁶⁶¹ Although some efforts by different energy institutions have been made to improve the energy sector through establishing few drafts and plans such as the "Oman energy master plan 2040" by PDO, "Energy conservation master plan in the power sector" by PAEW, and "National energy strategy" by PAEW, yet these drafted plans and strategies were submitted to the Council of Ministers since 2015 and still awaiting the ministers' approval.

⁶⁶² Interview with an official, Minister of oil and Gas

⁶⁶³ Interview with an official, Manager of Renewable Energy Research: The Research Council

There is no national energy policy yet. However, it is crucially important to develop one because energy policy will not only improve the energy sector specifically but will also work in parallel with the economic development, as implementing the action plans of national energy policy is of equal importance to implementing economic strategy(IA17).⁶⁶⁴

In line with this view, one of the respondents remarked that the Public Authority for Electricity and Water had appointed a consultant who has concluded a study. The aim of the national energy study was to recommend policy options on various aspects of fuel diversity and renewable energy (IEC2, 2015)⁶⁶⁵ to the government. This knowledge was further supported by other respondents who confirmed that thus far, no national energy policy for Oman was in place; however, the Public Authority for Electricity and Water has developed a proposal that is currently under review by the government (IA17, 2015)⁶⁶⁶ (IA6, 2015).⁶⁶⁷

By contrast, a small portion of the respondents indicated that they believed there was already an energy policy in place. For example, an official minister of the Supreme Council for Planning stated that “yes there is a national energy policy because there is energy sector” (IO14, 2015).⁶⁶⁸ While another interviewee responded more vaguely that he believed there was national energy policy in Oman, but despite working in the energy field, he did not refer to it (IEC23, 2015).⁶⁶⁹

The heterogeneous responses regarding the presence of an energy policy in Oman can be attributed to different definitions of energy policy. Using the definition provided above it can be concluded that no coordinated energy policy operated by a single entity in Oman exists, and that there has been poor communication between different groups, including the government, academics, and the private sector.

⁶⁶⁴ Interview with an official, Chairman of Peaceful Nuclear Energy: Ministry of Foreign Affairs

⁶⁶⁵ Interview with Electricity Company, Chief Executive Officer of Oman Power and Water Procurement Co (SAOC)

⁶⁶⁶ Interview with an official, Chairman of Peaceful Nuclear Energy: Ministry of Foreign Affairs

⁶⁶⁷ Interview with Sultan Qaboos University (SQU), Professor at SQU: Department of Electrical and Computer Engineering

⁶⁶⁸ Interview with an official, Minister: The Supreme Council for Planning

⁶⁶⁹ Interview with Electricity Company, Executive Director of Authority for Electricity Regulation

Three key findings can be concluded regarding the importance of energy policy to achieve sustainable energy development. The first finding showed that the energy sector in Oman does not have an existing national energy policy, which could not only enhance growth and economic diversification, but also ensure that energy resources are sustainable in terms of energy supplies. The second finding highlights that the sustainability and stability of the energy system relies not only on the implementation of policies and strategies, but also on an independent energy entity with full authority to operate the energy sector as well as act as the focal entity for assessing and coordinating the activities of ministries and government bodies. The third finding highlights that the availability and reliability of energy data is a challenge, not only because energy data are scattered between various energy institutions, but also because they are not recorded or accessible, hindering the assessment of the performance of the energy sector in achieving energy sustainability.

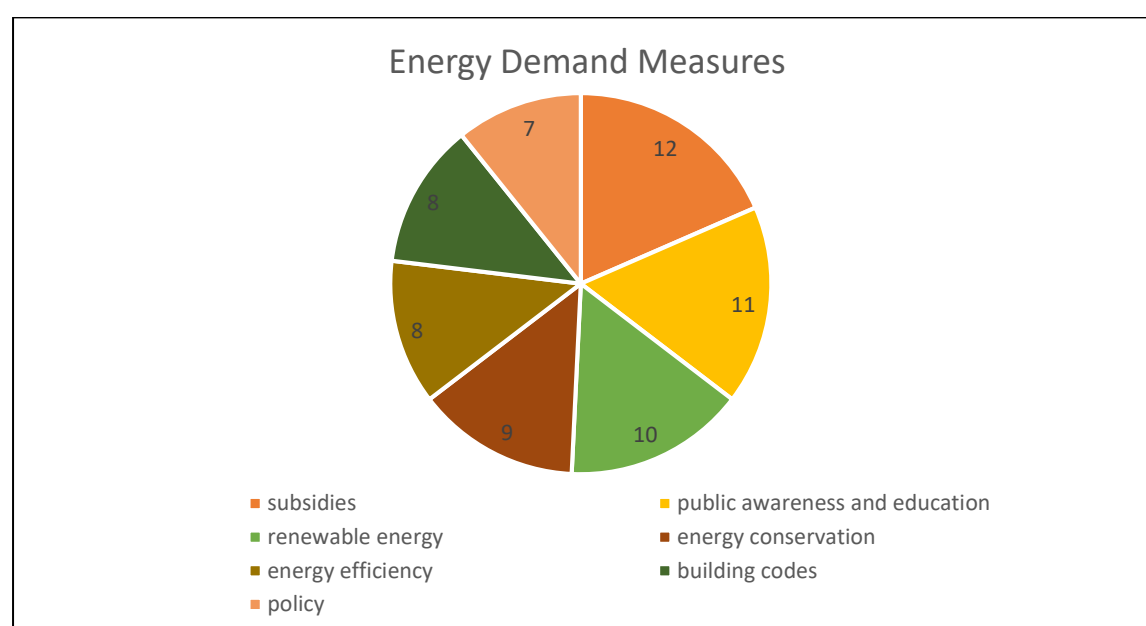
7.3 Domestic energy demand

This section provides an analysis of the impact of domestic energy demand on energy sustainability. The importance of energy demand management in achieving energy sustainability requires a strong understanding of the factors that affect the performance of an energy system and the resulting energy insecurity, which constitutes another challenge for energy sustainability.⁶⁷⁰ In Oman, the growing demand for energy has created a cumulative pressure on the Omani government to secure sufficient supplies of hydrocarbons. The following sections analyse the factors that influence the significant increase in energy demand in Oman, including population growth and movement to urban areas, industrialisation, low energy prices, energy use per capita and behaviour change, energy conservation and demand-side management, and energy efficiency.

To explore demand-side management measures, the interviewees were asked about what measures they thought should be focused on (Figure 7-4). Notably, votes were quite evenly distributed across the different measures, so no clear measure was most important to most people.

⁶⁷⁰ Hertog, S. and Luciani, G., 2009. Energy and sustainability policies in the GCC.

Figure 7- 4: Energy demand measures



Source: compiled by the author with data obtained from participants (2016)

7.3.1 Population growth and movement to urban areas

Population statistics describe the characteristics and behaviour of the population, including its size, growth, structure, and geographic distribution as well as the elements that drive population change (birth, death, and migration).⁶⁷¹ The population statistics in themselves do not provide indicators of sustainable wellbeing, but they highlight a variety of issues such as changes in the labour force, age of the population, and population sustainability.

However, the main population concern is not about the number of people as such, but rather the consumption of natural resources. A larger population generally means more demand for natural resources such as food, fresh water, minerals, and energy. Therefore, although many elements are needed to achieve more sustainable development, one of the most important elements is the need to provide sustainable energy.

The population of Oman is changing rapidly in terms of size and distribution. According to the World Bank, Oman's population grew from 0.6 million in 1960 to 4.5 million in 2016, an eight-

⁶⁷¹ Webarchive.nationalarchives.gov.uk. (2016). An overview of population and migration statistics - ONS. [online] Available at: <http://webarchive.nationalarchives.gov.uk/20160105222036/http://www.ons.gov.uk/ons/guide-method/method-quality/specific/population-and-migration/an-overview-of-ONS-s-population-statistics/index.html> [Accessed 10 Sep. 2018].

times increase.⁶⁷² This rapid expansion was in part caused by the beginning of the modern Renaissance in Oman in 1971, including upgraded infrastructure, improved economic development, improved per capita incomes, improved health and education services, and a larger labour market. These advances have also resulted in the return of many Omani migrants who were working in other countries.⁶⁷³ The official source of data on Oman's population is the results of the general census, which usually takes place every 10 years.⁶⁷⁴ The first population census in Oman was done in 1993, when the population (including Omanis and non-Omanis) was 2,018,074 people, and the most recent census was in 2010, when there were 2,773,479 people.⁶⁷⁵ Since 2010, the total population has almost doubled.

In conjunction with this population increase, a substantial increase in energy demand (electricity) has occurred, which comes not only from the overall increase in the Omani population (about 50% of electricity consumption comes from residential area), but also from the need for expansion in various sectors of the economy, such as industry, tourism, energy, and transportation. Therefore, another important energy demand measure is energy efficiency and conservation, to tackle the issue of matching energy supply with demand.

According to the 1993 population census, 968,975 (48%) people in the Omani population were men. Approximately 52% of the Omani population was younger than 14 years, about 45% were aged 15–64 years, and 3% were older than 64 years.⁶⁷⁶ Thus, in the near future, as the younger generation reaches adulthood, a sharp increase in energy consumption is to be expected because of the large increase in the number of houses, volume of traffic, and development of industrial and manufacturing businesses that will be needed. According to a study entitled “Families in the Sultanate of Oman” published recently by the National Centre for Statistics and Information (NCSI), more than 87% of Omani families own their houses rather than rent, reflecting the common attitude of Omanis that owning a house is essential. Table 7-2 illustrates the distribution of housing ownership and renting between Omanis and non-Omanis.

⁶⁷² The WB (2017) World bank indicators [online]. Available from: <http://data.worldbank.org/country/oman>

⁶⁷³ Al-Busaidi, M., 2012. *The struggle between nature and development: Linking local knowledge with sustainable natural resources management in Al-Jabal Al-Akhdar Region, Oman* (Doctoral dissertation, University of Glasgow).

⁶⁷⁴ NCSI (2012) Statistical yearbook. Muscat: National Centre for Statistics and Information.

⁶⁷⁵ Before 1993, no accurate or official national data exist, only estimations were provided by the Ministry of National Economy.

⁶⁷⁶ MONE (1993a) Statistical yearbook. Muscat: Ministry of National Economy.

Table 7- 2: Percentage distribution of housing ownership by nationality

Nationality of household	Owned	Rented	Provided by employer	Others
Omani	87.6%	11.6%	0.3%	0.5%
Non-Omani	0.7%	49.4%	49.9%	0

Source: Compiled by the author the data obtained from NCSI (2016).

The growth rate of Oman's population has increased because of the high birth rate and because of the increase in people migrating to Oman from other countries.⁶⁷⁷ Energy production capacity is significantly increasing to cope with the socioeconomic development of the country. However, this increase in energy consumption is generated from unsustainable fossil fuel resources, so less money can be generated through export of these resources. Therefore, Oman should pay special attention to other sustainable measures such as energy efficiency and conservation, subsidy allocation, and renewable energy resources, which are able to meet present and future energy demands.

Table 7-3 shows that in 2014, about 56% of the population of Oman were Omanis and 44% were non-Omanis (foreign workers and their families).⁶⁷⁸ Of all the regions on Oman, Al Batinah has the highest proportion of the Omani population (31.7%), followed by Muscat (20.8%). In terms of non-Omani nationals, the highest proportion is in Muscat, which has 41.8% of non-Omani nationals.

Table 7- 3: Total population registered in Oman by nationality and region in year 2014

Region	Omani Nationality (n=2,172,002)	Non-Omani (n=1,683,204)	Total (n=3,855,206)
Muscat	451,652 (20.8%)	704,209 (41.8%)	1,155,861 (30.0%)
Dhofar	182,070 (8.4%)	187,555 (11.1%)	369,625 (9.6%)

⁶⁷⁷ Since the discovery of Oman's oil reserves in 1960s, many expatriates have participated in the development of the national economy, and in the last 10 years, the industry sector has boomed, which required the use of external expertise and increased the population size substantially.

⁶⁷⁸ NCSI (2014) Statistical yearbook. Muscat: National Centre for Statistics and Information.

Musandam	24,300 (1.1%)	12,959 (0.8%)	37,259 (1.0%)
Al Buraymi	47,747 (2.2%)	48,866 (2.9%)	96,613 (2.5%)
Al Dakhliyah	298,574 (13.7%)	88,537 (5.3%)	387,111 (10.0%)
Al Batinah	689,048 (31.7%)	293,233 (17.4%)	982,281 (25.5%)
Al Sharqiyah	325,565 (15.0%)	166,648 (9.9%)	492,213 (12.8%)
Al Dhahira	131,914 (6.1%)	46,927 (2.8%)	178,841 (4.6%)
Al Wusta	21,132 (1.0%)	19,019 (1.1%)	40,151 (1.0%)
Not stated	0	115,251 (6.8%)	115,251 (3.0%)

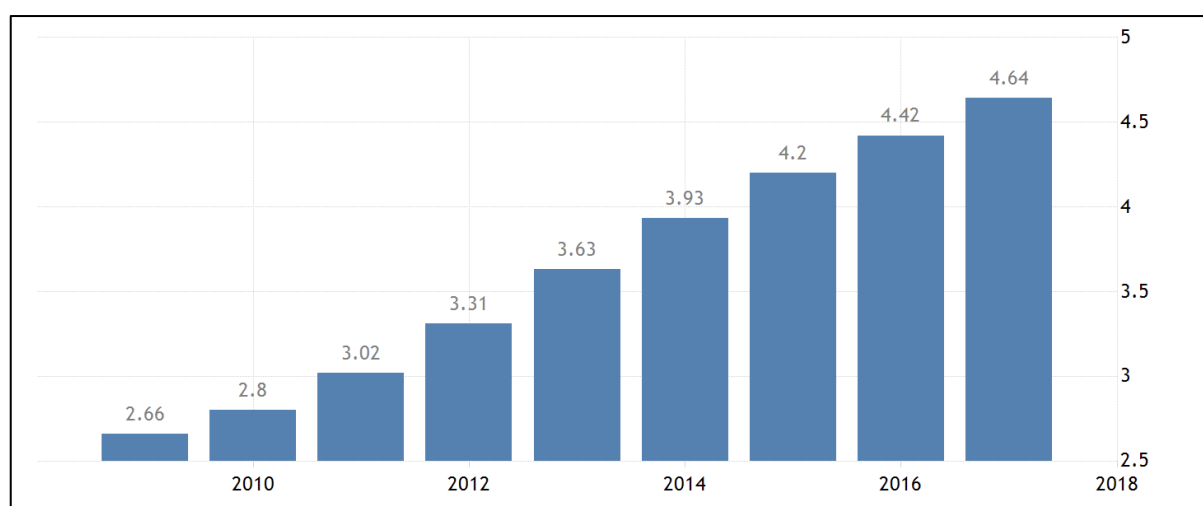
Source: Obtained from Statistical year book (2014), National Centre for Statistics and Information

The main reason for migration to Oman is for work in the development of Oman's infrastructure, which has now partly resulted in improvement in the health and education of the population, reduction of poverty, an increase in productivity, and rising per capita income of the population.

However, the negative effects of the large influx of immigrants to the country also affects the increase of energy demand because the subsidised energy tariffs are distributed equally to Omanis and non-Omanis. In other words, the increase in population size has resulted in great pressure on the Omani state budget, which must every year increase its contribution to subsidies for the energy tariffs. In 2017, the Omani government announced OMR 100 million for fuel subsidies for citizens.⁶⁷⁹

⁶⁷⁹ Oman Observer. (2017). RO 100 million to support citizens. [online] Available at: <http://www.omanobserver.om/ro-100-million-support-citizens/> [Accessed 10 Sep. 2018].

Figure 7- 5: Population growth in Oman, 2009-2017



Source: Statistical year book (2018), National Centre for Statistics and Information

Between 1985 and 2002, the population growth rate in Oman was 3.6% per year (figure 7-5). After 2002, the rate slowed to 2.3% per year as a result of advanced health services, better education, and public awareness of the need to minimise population growth.

About 57% of the Omani population are younger than 20 years, meaning that about 1,115,682 citizens will enter the workforce in the next 2–18 years. According to the International Labour Organization, 53% of the male population of Oman were economically active (ie, working) in 2011, the highest rate since 1990, with the lowest rate in 1996 at 46%. The proportion of women who were economically active has been much lower, with a low of 18.7% in 1995, and up to 24.2% in 2011.⁶⁸⁰ Usually, as people start working, they are more able to move to independent houses, and can afford to buy a car. Therefore, it is expected that energy demand will increase rapidly not only to fulfil the requirements of the growing population, but also to address the increasing energy use by the increase in numbers of houses, with appliances and vehicles, accompanying the general increase in income of individuals.

Clearly, a main contributor to the high demand for energy in Oman is the rapid increase in population size. The Omani population growth rate has fluctuated over the past 10 years, with the rate going from 5.4% in 2010 to 9.0% in 2012, but it remains greater than the average

⁶⁸⁰ Ilo.org. (2017). International Labour Organization. [online] Available at: <http://www.ilo.org/global/lang-en/index.htm> [Accessed 10 Sep. 2018].

worldwide population growth rate of 2% per year.⁶⁸¹ One of the main reasons for Oman's rapid growth is its increasing popularity as a destination for migration from other countries, which has been ongoing since Oman began its development process, opening up many more job opportunities.⁶⁸² Another strain on electricity supplies is internal migration to urban areas, which increases the intensity of and pressure on power supply in these areas.

7.3.2 Industrialisation

The Oman 5-Year Development Plans and Vision 2020 focus on diversification of income of the national economy away from the heavy reliance on oil, with a focus on the expansion of industrial projects to generate money for the economy. Oman has successfully built several industrial estates in different locations, such as Rusayl, Sohar, Salalah, Nizwa, Sur, Buraimi, and Samail. In addition to these industrial estates, there are three free zones—areas allowing immigrants special tax benefits and exemptions on investments—one located in Muscat and two in Salalah.⁶⁸³ These industrial projects are evidence that the Omani government has been encouraging the private sector to invest in the manufacturing industry.

However, some of these new projects are in energy-intensive industries such as petroleum refining, petrochemicals, cement, metal and steel, aluminium smelting, building materials, and fertilizer production. Therefore, to sustainably provide energy for this industrial expansion is a notable challenge with mainly gas used as a feedstock and for electricity production. According to the Authority for Electricity Regulation's annual report, one of the fastest growing energy consumption areas in Oman is the industrial sector, and its consumption is projected to increase substantially from 5,565 megawatts (MW) in 2015 to 9,529 MW in 2022 (8% annual growth rate), due to the rapid expansion of the industrial sector.⁶⁸⁴

The Omani government is aware of such growing demand for natural gas and the question is often raised of how to best balance this limited resource between domestic requirement and the

⁶⁸¹ The WB (2017) World bank indicators [online]. Available from: <http://data.worldbank.org/country/oman>

⁶⁸² Hertog, S. and Luciani, G., 2009. Energy and sustainability policies in the GCC.

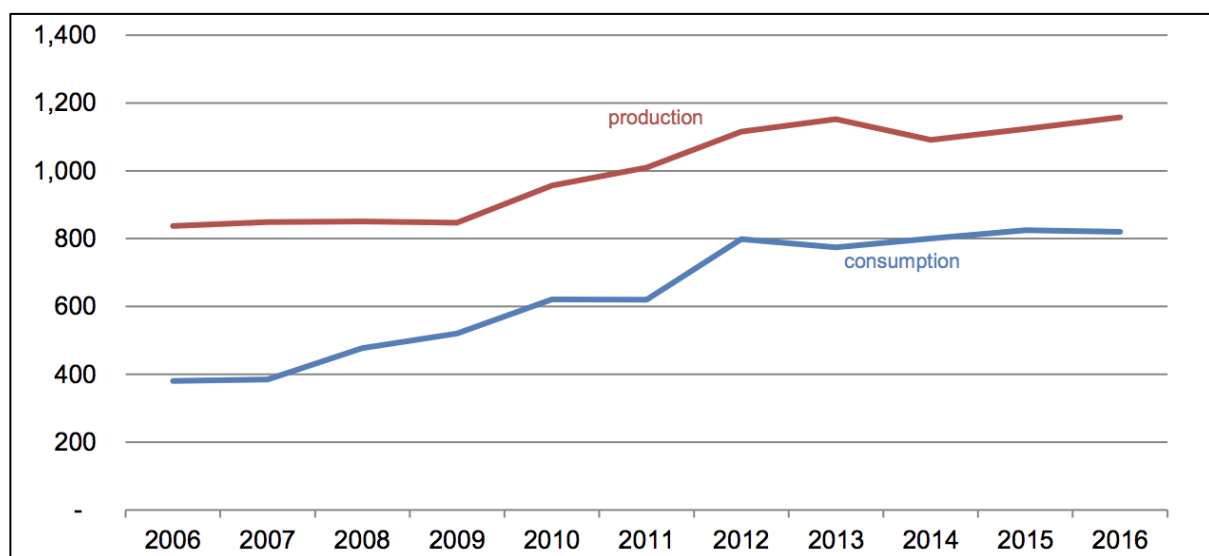
⁶⁸³ Anon, (2017). 60. The Public Establishment for Industrial Estates Oman. [online] Available at: <https://www.peie.om/ESTATES/About-Industrial-Estate> [Accessed 10 Sep. 2018].

⁶⁸⁴ OPWP (2016) Seven-year outlook report. Muscat: Oman power and Water Procurement Company.

long-term commitment to its export. Oil extraction requires large amounts of natural gas and rapid industrialisation also requires natural gas as a feedstock in the production of materials such as plastic, glass, paint, and most importantly for electricity generation. According to the World Bank, 97.5% of Oman's electricity generation has been fuelled from natural gas over the past decade, and oil sources accounted for the remaining 2.5%.⁶⁸⁵

According to the Oil and Gas journal, over the past 10 years Oman's consumption of natural gas increased from 380 billion cubic feet (Bcf) in 2006 to 820 Bcf in 2016. Oman uses more than 70% of its natural gas to meet its domestic requirements, and the remaining gas is exported. The proportion of natural gas available for export is shrinking noticeably as the domestic requirement is rapidly increasing because of the economic diversification plans to invest in various sectors of the economy (figure 7-6).⁶⁸⁶

Figure 7- 6: Oman natural gas production and domestic consumption (Billion Cubic Feet), 2006 to 2016



Source: Compiled by the author with data obtained from U.S Energy Information Administration (2017)

⁶⁸⁵ Oxford Business Group. (2016). The Report: Oman 2016. [online] Available at: <https://oxfordbusinessgroup.com/oman-2016> [Accessed 6 Sep. 2018].

⁶⁸⁶ The Oman government invested US\$15 billion to setup Duqm City, which has a strategic port, free zone, industrial estate, oil refinery, fisheries industries, dry dock, and an enormous oil storage facility, requiring a large amount of natural gas as a feedstock for all activities.

The Central Bank of Oman estimates that the demand for natural gas will continue to increase with the growing number of new energy-intensive industries combined with growing demand for electricity.⁶⁸⁷

However, few government policies consider industrial efficiency in Oman, even though some suggested time-of-use and cost-reflective tariff policies have concentrated on industry. Almost all industries across Oman are energy intensive, thus economic restructuring could be the only option to change industrial energy use over time. According to Lan et al. (2013), industrial efficiency can be improved immediately, and reductions in energy use of up to 30% and water use up to 80% could be possible.⁶⁸⁸

7.3.3 Subsidies and low energy prices

This section provides an analysis of the impact of low energy prices, specifically due to government subsidies, on energy demand, which can markedly hinder the achievement of energy sustainability. A subsidy can be defined as “any government action that concerns primarily the energy sector that lowers the cost of energy production, raises the price received by the producer or lowers the price paid by the consumers”⁶⁸⁹ and “any measure that keeps prices for consumers below market levels”.⁶⁹⁰

This section explores interviewee’s opinions of the following question related to energy subsidies: “Energy prices in Oman are currently subsidised. Do you believe such subsidies should be removed or at least targeted to low-income families through appropriate means?”. The majority of respondents suggested that subsidies should be removed gradually. The most common reason for this opinion was that the subsidies introduce inefficiencies in the market through incentivising careless, unsustainable energy consumption (IOC1, 2015;⁶⁹¹ IEC2, 2015).⁶⁹²

⁶⁸⁷ CBO (2016) Annual report. Muscat: Central Bank of Oman.

⁶⁸⁸ Glada Lahn, P.S. and Preston, F., 2013. Saving oil and gas in the gulf. *The Royal Institute of International. Chatham House Report Affairs*.

⁶⁸⁹ UNEP (2008) Annual report. United Nation Environmental Programme.

⁶⁹⁰ Ibid

⁶⁹¹ Interview with Oil Company, Retired Director from Petroleum Development Oman (PDO)

⁶⁹² Interview with Electricity Company, Chief Executive Officer of Oman Power and Water Procurement Co (SAOC)

Oman was the first GCC country to establish a cost-reflective pricing formula for its gas feedstock to the electricity sector.⁶⁹³ However, the Omani government has kept the cost of energy very low, both for liquid fuels (mainly for transportation) and electricity, as discussed in chapter four. According to the Authority for Electricity Regulation, the Omani government subsidised its electricity sector by at least \$ 1 billion in 2016.⁶⁹⁴ Although energy resources would generate significantly higher revenue if exported internationally, the government still heavily subsidises energy prices for domestic users, which has led to increased domestic demand. An interviewed government official cautioned against this unsustainable behaviour:

*“Low energy prices are encouraging an energy-inefficient building boom. The risk is that a threatening path-addiction to high consumption is being generated at a time when the costs of oil and natural gas exploitation are raising significantly, as oil and natural gas reserves are getting more difficult to access” (IO15, 2015).*⁶⁹⁵

Government energy subsidies create a burden on the Omani public budget. Not only do they encourage expansion of energy-intensive industries, but they also impact negatively on the balance of trade, because as more energy is used for domestic purposes, less is exported. For example, in the industrial sector, power generation and petrochemical production have used the widely available and fairly cheap gas feedstock, and some other industries such as steel and aluminium benefit from the cheap electricity that is almost totally generated from gas-fired power stations.⁶⁹⁶ Continuation of these energy-intensive behaviours will undoubtedly result in a gas shortage, because more than 97% of electricity is generated from gas-fired power stations.⁶⁹⁷ With the current large subsidies on energy, diversification to alternative energy types is unlikely to be a financially attractive option to producers, because the cost of conventional energy is far cheaper than investing in infrastructure for renewable or nuclear energies. Subsidies discourage many sectors from using potential alternative energy sources and also encourage wasteful behaviour. One respondent explained resident’s attitudes toward energy use:

⁶⁹³ Glada Lahn, P.S. and Preston, F., 2013. Saving oil and gas in the gulf. *The Royal Institute of International. Chatham House Report Affairs.*

⁶⁹⁴ AER (2016) Annual report. Muscat: The Authority for Electricity Regulation.

⁶⁹⁵ Interview with an official, Chairman of the Public Authority for electricity and Water

⁶⁹⁶ Thegulfintelligence.com. (2013). The Gulf Intelligence Oman Energy Forum. [online] Available at: <http://www.thegulfintelligence.com/en/gi-gallery/the-gulf-intelligence-oman-energy-forum-21102013> [Accessed 12 Sep. 2018].

⁶⁹⁷ AER (2012) Annual report. Muscat: The Authority for Electricity Regulation.

Many people are not appreciating the low electricity prices so we can see that many people are placing many lights outside their houses more than they need. Also, they install extra air conditioning units and leave these units running all the time without turning them off. I think people have to realise the importance of reducing energy consumption and ways we can save energy (IA18, 2015).⁶⁹⁸

One interviewee reasoned that subsidies always create distortions and there was always a risk of negative implications. He also argued that subsidies need to be removed to achieve sustainable energy consumption and to thereby keep the demand for energy at reasonable levels (IO13, 2015).⁶⁹⁹ However, many respondents argue that energy prices without subsidies will be too high for most low-income families, and this should be considered when removing the subsidies, because these subsidies were originally intended to help low-income families (IO15, 2015;⁷⁰⁰ IA21, 2015;⁷⁰¹ IEC3, 2015⁷⁰²)

Subsidies are often implemented with the aim of helping low-income families to access energy with low tariffs, protecting the end user, controlling inflation, mitigating the effects of global price fluctuations, and equally distributing resources and wealth to local people. However, the International Monetary Fund, United Nations Development Programme, and World Bank have stressed the negative impacts of subsidies. These international organisations have examined the social effects of such subsidies, and have found that the subsidies can intensify pressure on a fiscal budget and crowd out public spending on priorities such as health, fisheries, agriculture, education, and resource allocation.⁷⁰³ Also, although subsidies are meant to support low-income families, the reality is that most benefits are allocated to high-income families, thus encouraging inequality and inefficient use of energy.⁷⁰⁴

The next interview question assessed potential implications of subsidies on transitioning towards more energy sustainability as follows: “Do subsidies hamper a transition towards more

⁶⁹⁸ Interview with an academic, Sultan Qaboos University, Professor at Department of Electrical and Computer Engineering

⁶⁹⁹ Interview with an official, Secretary General of the Research Council

⁷⁰⁰ Interview with an official, Chairman for the public Authority for Electricity and Water

⁷⁰¹ Interview with an academic, Sohar University, Assistant Professor

⁷⁰² Interview with Electricity Company, Chief Executive Officer, Rural Area Electricity Company (SAOC)

⁷⁰³ Meltzer, J., Hultman, N.E. and Langley, C., 2014. Low-carbon energy transitions in Qatar and the Gulf Cooperation Council region.

⁷⁰⁴ Fernandez, E., Saini, R.P. and Devadas, V., 2005. Relative inequality in energy resource consumption: a case of Kanvashram village, Pauri Garhwal district, Uttranchal (India). *Renewable energy*, 30(5), pp.763-772.

sustainability””? Chapter 2.2 defined energy sustainability according to Munasinghe (2002) as: ensuring the sustainable use of energy and that materials obtained from the biosphere are not depleted, and the regeneration of resources (carrying capacity) has to be greater than or equal to their consumption. According to this definition, two factors play a key role: whether the source of the energy can be depleted and the extent of energy consumption. Although respondents had mixed levels of understanding of the issue of subsidies, most felt that subsidies are encouraging consumers to use more energy and that the adverse effects of these subsidies are causing exploitation of oil and natural gas resources. Mehrara noted that subsidies in oil-exporting countries explain their otherwise “implausibly high energy intensity” that has triggered energy consumption to rise much faster than overall economies.⁷⁰⁵ Deutsche Bank assessed the growing domestic energy consumption in the GCC and found that demand has increased by 56% over the past 10 years, which is more than four times faster than the world average of 13%.⁷⁰⁶

This section identifies that one of the major challenges facing sustainability in the energy sector in Oman is the low energy prices created by subsidies from the government, which in turn has encouraged a culture of careless energy consumption.

7.3.4 Energy use per capita and behaviour change

This section addresses the impact of low energy prices on energy use per capita and energy consumer behaviour. As described above and in chapter 2, the Omani government subsidises the energy sector heavily. Policy makers in Oman are aware of the rapid increase in energy demand and the Oman Power and Water Procurement Company (OPWP) uses the 7-year statement to ensure that the production capacity meets the expected demand.⁷⁰⁷ However, it is not sustainable to manage energy demand by increasing electricity generation alone, and extent of energy use should also be addressed, as described by government official:

“Meeting the increasing demand of energy by constructing new electricity power plant alone is not sustainable in the long run, government policies

⁷⁰⁵ Mehrara, M., 2007. Energy consumption and economic growth: the case of oil exporting countries. *Energy policy*, 35(5), pp.2939-2945.

⁷⁰⁶ Lewis, M.C. and Hsueh, M., 2012. Crude oil: iceberg glimpsed off West Africa. *Energy market research report*, Paris: Deutsche Bank.

⁷⁰⁷ OPWP (2017) 7-year statement 2017-2023. Muscat: Oman Power and Water Procurement Company.

should be revised and include other measures of managing this energy demand by introducing programmes into the education system and increasing public awareness that people should save energy” (IO11, 2015).⁷⁰⁸

An interviewed academic also suggested a similar idea for increasing public awareness of the problems associated with high energy use:

“That could be achieved through educating people about energy usage, and this can be applied in schools so people grow up with the concept of saving energy, which will definitely lead to less energy consumption” (IA7, 2015).⁷⁰⁹

According to the Omani National Centre for Statistics and Information, during the past four decades, electricity consumption per capita in Oman has increased dramatically, from 2,000 kWh in 1990 to 6,500 kWh in 2014, representing an average growth rate of 5–10% per year.⁷¹⁰ By comparison, the average per capita electricity consumption in the UK is 5,100 kWh per year, and 3,000 kWh per year is the world average (Figure 7-7). Interviewees were confident that energy consumption in Oman was growing at a faster rate than the population (IO17, 2015;⁷¹¹ IA19, 2015;⁷¹² IOC12, 2015⁷¹³). One interviewee from an electricity company noted that the growth in electricity demand could not be explained by a growth in the population itself, but in the consumption per capita. He estimated that the consumption per capita in Oman has increased by up to 50% in the past 7 years (IEC2, 2015).⁷¹⁴

⁷⁰⁸ Interview with an official, energy and industry director at the Research Council

⁷⁰⁹ Interview with an academic, Sohar University, Associate Professor

⁷¹⁰ NCSI (2014) Statistical yearbook. Muscat: National Centre for Statistics and Information.

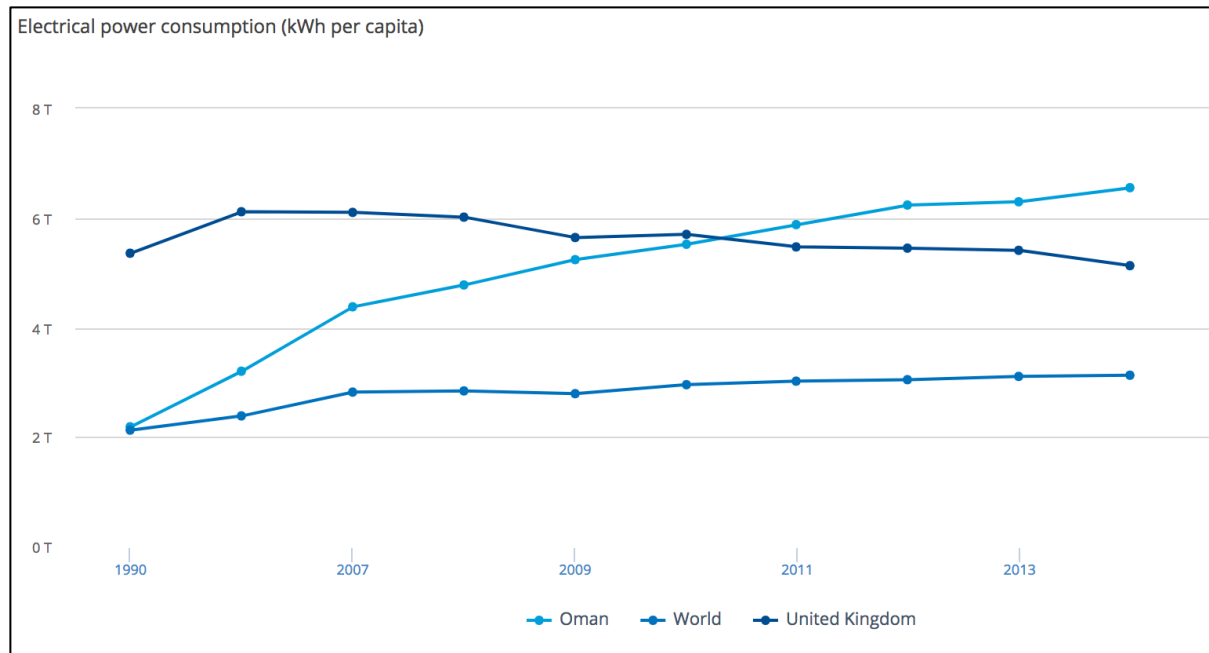
⁷¹¹ Interview with an official, Chairman of Peaceful Nuclear energy, Ministry of Foreign Affairs

⁷¹² Interview with an academic, Caledonian College of Engineering, Research Professor and Head Caledonian Centre for Creativity and Innovation.

⁷¹³ Interview with Oil Company, new Venture Director, CC Energy Limited.

⁷¹⁴ Interview with Electricity Company, Chief Executive Officer of Oman Power and Water Procurement Co (SAOC).

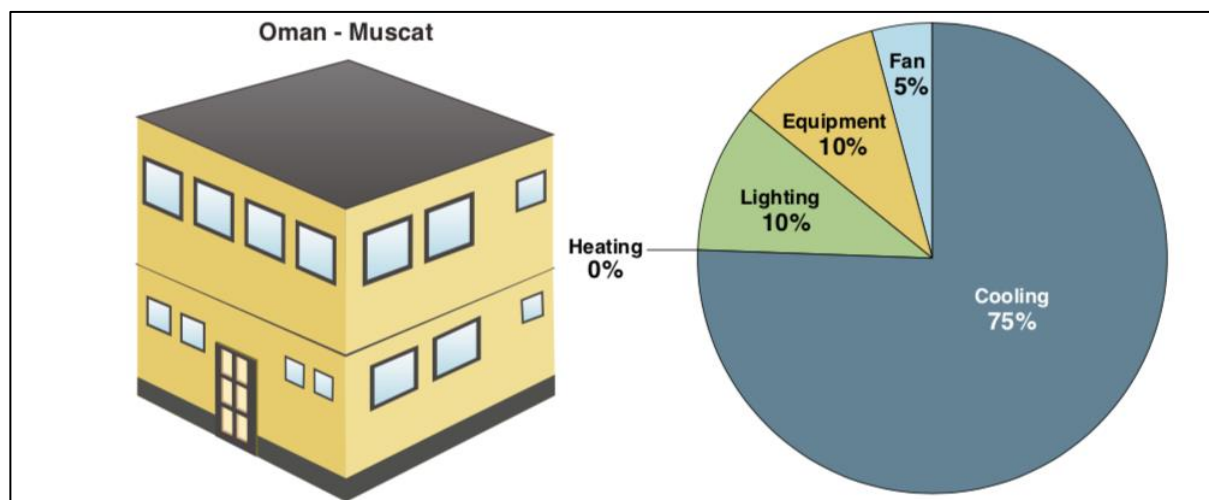
Figure 7- 7: Electricity power consumption (kWh per capita) from 1990 to 2014



Source: compiled by the author from data obtained from the World Bank (2017), electric power consumption

Figure 7-7 shows that the consumption of electricity in Oman reached the same level of that of the UK in 2010, after which Oman's consumption continued to increase while the UK's decreased. Oman's electricity consumption is much higher than the world's average, partly because of the geographic location of Oman. In the hot summers, 70–80% of total electricity consumption is dedicated to air conditioning (Figure 7-8).

Figure 7- 8: Annual electricity consumption rate by using different appliances



Source: Dubey and Kararti, 2017⁷¹⁵

As mentioned above when discussing subsidies, another factor that leads to high electricity demand is the behaviours and attitudes of residents.

More must be done to encourage energy savings and change peoples' energy use behaviours and attitudes, because a wide-scale behavioural change is needed to reduce energy demands.

7.3.5 Energy conservation and demand-side management

Energy conservation can play a central role in reducing the total energy consumption of a country.⁷¹⁶ According to the Scottish Environment Protection Agency, energy conservation is the highest sustainable energy priority because it improves pollution levels, national energy security, and reduces resource depletion.⁷¹⁷

Most of interviewees acknowledge the importance of energy conservation in achieving energy sustainability. Many stress that energy conservation requires effective policy interventions to regulate and incentivise the current use of energy, as described by an interviewed academic:

“Oman has to follow energy conservation measures because a lot of energy is going on wastages especially in the electricity sector in terms of utilization of energy by different stakeholders and these all standard policies have to be introduced so that will reduce energy consumption” (IA19, 2015).⁷¹⁸

Meanwhile, some participants comment that the key challenge regarding energy conservation is the inefficient government institutions and the weak political will to implement conservation measures, as mentioned by one government official interviewee:

“Right now, the Oman Power and Water Procurement Company is collecting and analysing data and producing a 7-year plan. However, this

⁷¹⁵ Krarti, M. and Dubey, K., 2017. Energy productivity evaluation of large scale building energy efficiency programs for Oman. *Sustainable Cities and Society*, 29, pp.12-22.

⁷¹⁶ Herring, H., 2006. Energy efficiency—a critical view. *Energy*, 31(1), pp.10-20.

⁷¹⁷ Sepa.org.uk. (2010). SEPA's Energy position statement. [online] Available at: https://www.sepa.org.uk/media/59374/sepa_energy_position_statement.pdf [Accessed 12 Sep. 2018].

⁷¹⁸ Interview with an academic, Caledonian College of Engineering, Research Professor and Head Caledonian Centre for Creativity and Innovation

organisation is focusing on the supply side instead of the demand side, establishing how to meet the expected electricity demand by altering supply. Thus, I think we should have a separate organisation with its own mandates for tackling the issue of the demand side of energy, rather than coupling it up with the OPWP itself, because it is a separate issue” (IO10, 2015).⁷¹⁹

Another interviewed government official highlighted that energy subsidies should be reformed through education and awareness programmes and communication strategies, and gives a good example of energy conservation implemented in Morocco:

“Morocco implemented a well-planned strategy within the framework of its national energy policy, which was a communication strategy that educates its people about the importance of energy subsidy reform to conserve energy. This comprised newspaper articles, public TV and radio discussion, conferences, various reform steps, and debates highlighting the economic and social benefits for the reform of the prices (including the availability of more money allocating for investment somewhere else)” (IO4, 2015).⁷²⁰

Another interviewed government official stated that the application of energy conservation is something that can be achieved without too much time investment:

“I believe that energy conservation is important more than other measures, because we can start implementing it tomorrow, without the need to study hard nor invest heavily” (IO16, 2015).⁷²¹

One essential technique for conserving energy is through implementing demand-side management. This technique usually encourages consumers to use less energy during peak hours or shift the time of energy use to the off-peak hours such as night-time and weekends. Demand-side management allows a reduction of the overall load on an electricity network and has various beneficial effects.⁷²² First, reducing the overall energy burden by demand-side management can make cost savings. Various energy conservation and demand-side management efforts have been applied in the context of integrated resource planning and intended to reduce total costs of meeting energy demand. Second, it can result in social and

⁷¹⁹ Interview with an official, Assistant Secretary General for Programs and Research, the Research Council

⁷²⁰ Interview with an official, Manager of Renewable Energy Research: The Research Council

⁷²¹ Interview with an official, Minister of Oil and Gas, Ministry of Oil and Gas

⁷²² Strbac, G., 2008. Demand side management: Benefits and challenges. Energy policy, 36(12), pp.4419-4426.

environmental improvement by conserving resources and reducing greenhouse gas emissions. Third, it can reduce consumption and eliminate the need to build new power plants.

Oman's first demand-side management study was titled "The Study on Demand Supply Management for the Power sector in the Sultanate of Oman" in 1998, which was done with help from the Japan International Cooperation Agency (JICA).⁷²³ The study explored several plans for potential load management, including implementing gas cooling systems for government premises, hotels, hospitals, commercial buildings, and big houses, and moving some of the load from peak to off-peak time in some sectors such as the industrial and commercial sectors through the application of ice thermal storage systems as well as by introducing time-of-use tariffs.⁷²⁴ However, the study recommendations were never implemented, a common problem due to the complexity and bureaucracy of the system, as well as costs. According to an interviewed electricity company participant highlights:

"I think the problem in Oman is that the government pays a lot of money to international consultants to find a solution for a certain issue, but unfortunately many recommendations are kept on the shelves and never get to the implementation stage" (IEC, 2015).⁷²⁵

Another demand-side management study was conducted by the Sultan Qaboos University in 2007. The study estimated energy savings and load management potential of the government and commercial sectors and estimated the potential effects of these changes on electricity generation in Oman. The study identified that demand-side management is economically feasible from the consumers' perspective, because the discounted payback period of investment in efficient air conditioning and lighting is estimated to be 4–12 years, even despite the other tariffs being subsidised. From the perspective of energy producers, the overall energy savings for electricity generation are estimated to be between \$416 and \$597 million.⁷²⁶ One academic participant highlighted that subsidies on the energy sector are causing a significant pressure on

⁷²³ Gastli A., Al-Badi A.H., & Malik A.: 2011, Sustainable energy usage in Oman: Opportunities and barriers

⁷²⁴ JICA (1998) The study on demand supply management for power sector in Sultanate of Oman. Japan International Cooperation Agency.

⁷²⁵ Interview with Electrical Company, Chief Executive Officer, Rural Area Electricity Company (SAOC)

⁷²⁶ Malik, A.S., 2007. Impact on power planning due to demand-side management (DSM) in commercial and government sectors with rebound effect—A case study of central grid of Oman. *Energy*, 32(11), pp.2157-2166.

the fiscal budget, and that implementation of demand-side management can allow huge cost savings for the government (IA6, 2015).⁷²⁷

Furthermore, another government official participant stressed that the key challenge for demand-side management is the weak political will toward the introduction of policies that regulate energy demand:

“I’m aware of a study of demand-side management energy savings that was done on a smaller scale at the Oman Royal Court of Affairs government sector, which found that savings of 25% were possible by developing policies that regulate energy demand. For instance, changing the temperature setting during the peak load hours from 20 to 24°C could lead to substantial savings. However, the Omani government has not shown any serious attempts at applying time-of-use tariffs nor creating incentives to encourage consumers to use more efficient appliances” (IO15, 2015).⁷²⁸

By contrast, other respondents argue that energy conservation comes from people’s willingness to change their behaviour to save energy. According to an interviewed academic respondent (IA7, 2015),⁷²⁹ energy conservation measures by themselves are inadequate to lower energy consumption, if people in the buildings are not actively involved in the process. Clearly, a combined effort of government policy making and culture change is needed.

7.3.6 Energy efficiency

Energy efficiency reduces the overall consumption of energy and the impact on the environment. Most countries increase their energy efficiency as they develop, by increasing their output from the same input of energy. In other words, they decrease the total energy intensity of their national economies in relation to primary energy consumption per unit of GDP. Energy efficiency saves money by implementing energy-saving measures, including the use of building materials that reflect sunlight and insulation that lowers the heating load of buildings. According to Mahroum, energy efficiency decreases energy consumption by 30%,

⁷²⁷ interview with Sultan Qaboos University (SQU), Professor, Department of Electrical and Computer Engineering.

⁷²⁸ Interview with an official, Chairman of the Public Authority for electricity and Water.

⁷²⁹ Interview with an academic, Sohar University, Associate Professor

water consumption by 30%, and the overall cost by 50–70%.⁷³⁰ Estimations like these justify the growing global concerns around the construction sector, leading companies to use measures that are not only energy efficient, but also environmentally friendly. The global existence of government incentives and regulation frameworks has attracted wide interest in the use of sustainable energy efficiency.⁷³¹ Therefore, governments are aware of the urgent need to enhance environment-friendly construction concepts. These types of construction measures have various effects, including reducing energy consumption and saving resources (oil, natural gas, and water), protecting the environment by reducing waste and pollution, and thus promoting more healthy living environments.⁷³²

However, in most GCC countries, including Oman, energy demand is increasing together with intensity.⁷³³ This increasing energy demand is attributed to several factors, including growth in the population, improving living standards, increasing GDP, low energy prices, and inefficient home appliances such as air conditioning.⁷³⁴ In addition, the trend of energy intensity in these countries is moving in the opposite direction from most other countries around the world, with increasing energy intensity and less efficiency. Figure 7-9 illustrates Omani energy intensity measured against the Organisation for Economic Co-operation and Development (OECD) and the world between 1990 and 2014.

⁷³⁰ Mahroum, S., 2011. Construction Projects in the GCC: the opportunity and the missing link for a GCC-based eco-innovation. *Retrieved January, 10*, p.2015.

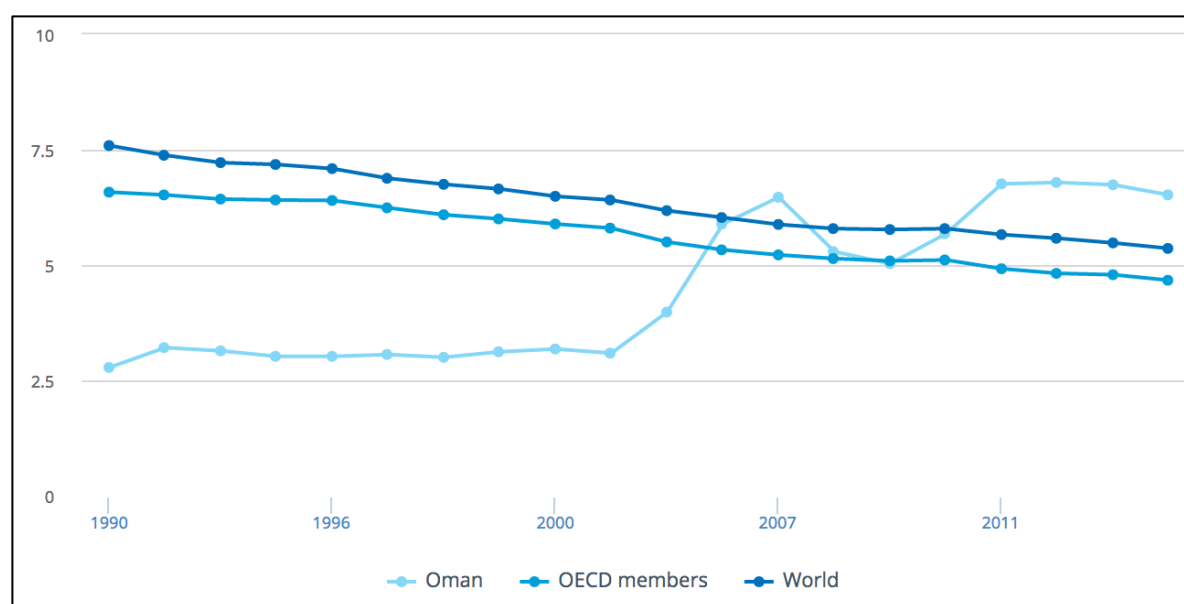
⁷³¹ Sidawi, B. and Meeran, S., 2011. A framework for providing lifelong finance to the owners of affordable dwellings in the Kingdom of Saudi Arabia. *Cities*, 28(2), pp.138-146.

⁷³² Al-Rimmawi, H. and Surinder, B., 2007. Government's Role in Saudi Arabian Village Development: The Case of Al-Yazeed.

⁷³³ Stevens, P. and Lahn, G., 2011. Burning Oil to Keep Cool: The Hidden Energy Crisis in Saudi Arabia. *Chatham House, London*.

⁷³⁴ Low energy prices have reduced the incentive to invest in energy-efficient equipment and infrastructure.

Figure 7- 9: Energy intensity of primary energy (MJ/\$20 PPP GDP) for Oman, OECD, and the World (1990-2015).⁷³⁵



Source: Compiled by the author, data obtained from the World Bank indicators (2017)

The heavy investments in inefficient transportation, industrial infrastructure, and buildings have had long-term negative effects not only on energy efficiency and intensity, but also producing harmful effects on the environment through contributing to greenhouse gas emissions through the intensive consumption of oil and natural gas.⁷³⁶

One example of inefficient energy use can be seen in the buildings in the GCC, and Oman in particular. Buildings are poorly designed and constructed because most were made under the impression of the indefinite availability of cheap energy resources. Most buildings do not have reliable insulation, efficient windows, shading, or efficient appliances. Households are responsible for about 50% of energy consumption in Oman, which is mostly attributed to air conditioning.⁷³⁷ In recognition of this challenge, policies are needed to address residential energy use. According to Krane, policy makers can consider several measures to improve efficiency in buildings, as follows:⁷³⁸

⁷³⁵ Energy intensity of primary energy is the ratio between GDP and energy supply calculated at purchasing power parity. It calculates the energy input used to produce one unit of economic output. A lower ratio indicates less energy used to produce one unit of output.

⁷³⁶ Dincer, I., 1999. Environmental impacts of energy. *Energy policy*, 27(14), pp.845-854.

⁷³⁷ AER (2012) Annual report. Muscat: The Authority for Electricity Regulation.

⁷³⁸ Krane, J., 2010. Energy Conservation Options for GCC Governments. *Dubai School of Government Policy Brief*, (18).

1. Enforce standards on new construction to encourage best practice in efficiency such as the USA's Leadership in Energy and Environmental Design (LEED), Canada's EnerGuide for Houses, and the Environmental Assessment Method in the UK.⁷³⁹
2. Incentivise builders, home owners, and tenants to use energy efficiently and reduce energy use. In western countries, tax credits are frequently used for this purpose. However, GCC countries, including Oman, have few taxes, and so these incentives are not generally considered.
3. Integrate low-energy passive measures such as natural light, natural ventilation, evaporative cooling, shading, insulation, solar control, and active measures.
4. Promote automated building management to control cooling and ventilation systems, and turn off unused air conditioning and lighting.
5. Enforce rules that reduce energy use and carbon emissions across the government, commercial, and private sectors.

Interviewees were asked about their views on the importance of introducing energy efficiency rules and regulations. Specifically, the role of thermal insulation of buildings as one of the energy-saving measures to reduce the energy consumption used in buildings for cooling purposes. All respondents confirmed that energy efficiency should play an important part in the national energy policy. An interviewed electricity company participant expressed his views on the importance of building insulation:

"I think insulation for buildings is very important when considering energy efficiency because in this country we have very high temperatures. The current materials that are used in the construction sector are high heat observant and require cooling systems to cool them, which consume massive amount of electricity. I believe the government should put insulation as a requirement when issuing building permits" (IEC3, 2015).⁷⁴⁰

Furthermore, an interviewed government official highlighted that the role of the orientation of buildings in sustainable design:

"This is critical for sustainable design if we look at our traditional architecture in Oman then you could see that the role of the orientation plays

⁷³⁹ Many of these measures developed from the Climate Group, Smart 2020: Enabling the low carbon economy in the information age. Website: <https://www.theclimategroup.org/sites/default/files/archive/files/Smart2020Report.pdf>

⁷⁴⁰ Interview with Electricity Company, Chief Executive Officer, Rural Area Electricity Company (SAOC).

a key role, especially for us here the sun is very strong and it significantly impacts the cooling load of buildings. Unfortunately, the current orientation of buildings follows the direction of roads instead of the appropriate orientation of buildings in terms of sun's path. So, I think Ministry of Housing should take this as a priority and should take urgent actions in this regard" (IO13, 2015)⁷⁴¹

Furthermore, additional energy efficiency measures, such as building codes and low energy consumption appliances were mentioned by one interviewed academic:

"We can look at the types of windows, for example if we install double glazing and low energy consumption appliances, which can have direct impacts on energy consumption" (IA7, 2015).⁷⁴²

By contrast, many participants took an opposing view, that laws should not be made to adopt thermal insulation in buildings because this measure would be against the interest of low-income families because it adds to the cost of construction (IO17, 2015;⁷⁴³ IA20, 2015;⁷⁴⁴ IO24, 2015⁷⁴⁵). One interviewed government official suggested that there should be some sorts of mechanisms that are well planned and controlled by the government to subsidise the uses of insulation for low-income families (IO16,2015).⁷⁴⁶ The following example was provided by an academic participant:

"First of all, subsidies should go to low-income families. Second, subsidies can be directed to support initiatives to deploy for example solar rooftop projects on the top of residential buildings, instead of subsidies being given to the conventional power plants" (IA6, 2015).⁷⁴⁷

Some GCC countries have different techniques to improve energy efficiency of appliances and equipment. For example, in the UAE, the Authority for Standardization and Metrology has started rating the efficiency of air conditioning systems, which are rated in terms of a star system. Air conditioners that do not meet the minimum criteria cannot be imported into the

⁷⁴¹ Interview with an official, Secretary General of the Research Council.

⁷⁴² Interview with an academic, Sohar University. Director of Environment Research Centre.

⁷⁴³ Interview with an official, Chairman of Peaceful Nuclear Energy, Ministry of Foreign Affairs

⁷⁴⁴ Interview with an academic, Professor at Caledonian College of Engineering

⁷⁴⁵ interview with an official, Minister of the Supreme Council for Planning

⁷⁴⁶ interview with an official, Minister of oil and gas

⁷⁴⁷ Interview with Electricity Company, Chief Executive Officer, Rural Area Electricity Company (SAOC)

country.⁷⁴⁸ Another example is Saudi Arabia, which monitors the standards and implementation of the national energy efficiency appliance labelling programmes for buildings and materials as well as mandates standards for appliance efficiency.⁷⁴⁹

The Omani government has shown some interest in energy efficiency⁷⁵⁰. For example, in 2013 the Public Authority for Electricity and Water with help from the Japan International Cooperation Agency (JICA) produced a conservation and efficiency master plan for the energy sector to reduce energy consumption, but few examples have yet been implemented regarding standards and labelling for appliance and technological device efficiency.⁷⁵¹

7.4 Diversification of energy resources

Energy sustainability studies have highlighted the importance of diversification of resources, impressing that it should be one of the main elements of an energy portfolio, as discussed in chapter two. This section analyses participants' perceptions of diversification policy for sustainable development in the Omani energy sector. Participants were asked whether Oman should introduce renewable energy resources to its energy sector. The majority of interviewees noted that renewable energy resources have not yet been properly introduced in Oman's energy policy, and this was attributed to several causes. The key reason was that oil and natural gas are currently abundant for domestic use as well as for export. According to a BP statistical report, at the end of 2014, Oman had 5.5 billion barrels of proven oil reserves and 33.5 trillion cubic feet of natural gas.⁷⁵² One interviewed oil company participant reflected on this:

⁷⁴⁸ Karlsson, P., Decker, C. and Moussalli, J., 2015. Energy efficiency in the UAE: Aiming for sustainability. *Strategy&*, June, 4, p.2015.

⁷⁴⁹ Dubey, K., Howarth, N. and Krarti, M., 2016. Evaluating Building Energy Efficiency Investment Options for Saudi Arabia. *King Abdullah Petroleum Studies and Research Center (KAPSARC), Riyadh*, www.kapsarc.org/wp-content/uploads/2016/10/KS-1655-DP049A-Evaluating-Building-Energy-Efficiency-Investment-Options-for-SA_web.pdf.

⁷⁵⁰ Despite some efforts by different governmental institutions have been made to enhance the energy sector through creating drafts and plans such as the "Energy conservation master plan in the power sector" by PAEW, "Oman energy master plan 2040" by PDO, and "National energy strategy" by PAEW, but these drafted plans and strategies were not approved yet. However the "Oman energy master plan 2040" was altered to a programme named: "Oman Energy Industry-Academia R&D Protocol".

⁷⁵¹ Paew.gov.om. (2013). Project for Energy Conservation Master Plan in the Power Sector in the Sultanate of Oman. [online] Available at: <https://www.paew.gov.om/PublicationsDoc/RE-JICA-final-report> [Accessed 16 Sep. 2018].

⁷⁵² Workbook, H.D., 2014. BP Statistical Review of World Energy:[6].

“Obviously, oil and natural gas are available commodities in Oman not only for industrial applications and power generation but also for export, which I think these resources will play the dominant role at least over the next 20–30 years” (IOC1, 2015).⁷⁵³

Some respondents (IEC3, 2015;⁷⁵⁴ IO11, 2015⁷⁵⁵) highlighted that no policy is in place that envisages the introduction of renewable energy sources in Oman. An interviewed academic explained his view on the absence of these policies:

“I believe that Oman has been left behind in terms of renewable energy, and it is very important now that political decisions are being taken in a serious consideration to catch up with the rest of the world. I believe Oman has now adequate intellectual and financial resources to include renewables in the energy portfolio. It is only until 2007 that the previous ‘fear and distrust’ of renewable energies on the part of Oman as an oil and gas producer country had changed into a realization that renewables were an essential component of their national energy supplies, as well as a global strategic option for both extending the life of oil and gas reserves and reducing carbon dioxide emissions, and thus combating climate change. Therefore, we should have strong political support to have renewable energy resources as a part of the energy mix in Oman” (IA6, 2015).⁷⁵⁶

The subsidised costs of domestic fossil fuels in Oman are much less than those of renewable energy resources, creating a barrier to their implementation. One governmental official inferred that subsidies caused distortion, which makes it necessary to remove subsidies wherever possible (IO13, 2015).⁷⁵⁷ Furthermore, one respondent plainly adds:

“If oil and gas stay cheap people will not get used to the concept of renewable energy” (IA21, 2015).⁷⁵⁸

Other respondents spoke about the high initial capital investment needed for renewables and that the infrastructure is not ready for such technology yet. Adding to this, one governmental official participant said:

⁷⁵³ Interview with Oil Company, Retired Director from Petroleum Development Oman (PDO)

⁷⁵⁴ Interview with Electricity Company, Chief Executive Officer, Rural Area Electricity Company (SAOC)

⁷⁵⁵ Interview with an official, Energy and Industry Director at the Research Council

⁷⁵⁶ Interview with Sultan Qaboos University (SQU), Professor at SQU: Department of Electrical and Computer Engineering

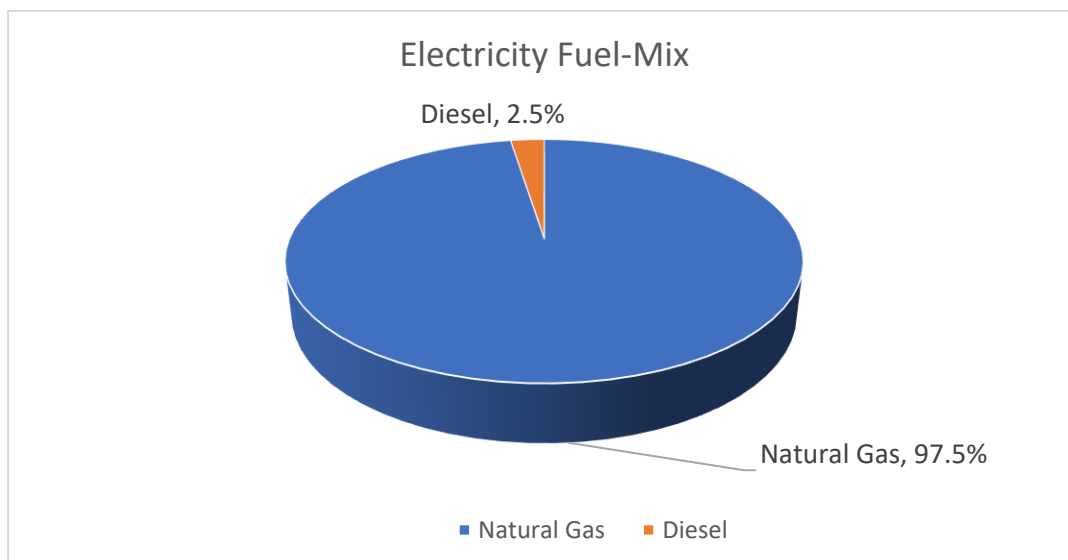
⁷⁵⁷ Interview with an official, Secretary General of the Research Council

⁷⁵⁸ Interview with an academic, Sohar University, Assistant Professor

“Renewable energy-based technologies are in general still a work-in-progress and the technology is not mature enough to be introduced in Oman” (IO16, 2015).⁷⁵⁹

Another factor that slows the progress of energy diversification in Oman is that the current domestic energy supply of oil and gas satisfies almost all local energy service demands, including transportation, industrial, and water and electricity generation. For example, the energy mix in the electricity sector consists of 97.5% natural gas, which is used to fire electricity plants across the country, and another 2.5% of electricity is produced from diesel fuel to power rural areas that are disconnected from the grid (Figure 7-10).

Figure 7- 10: Total electricity fuel mix in Oman, 2017



Source: Compiled by the author with data obtained from NCSI, 2017

However, although a few pilot projects have been commenced by several institutions in Oman for the purpose of assessing the capability of the renewable energy technologies under Oman’s environmental and weather conditions, the absence of a legal framework and slow validation procedures have caused delays.⁷⁶⁰ For example, Petroleum Development Oman (PDO) has recently started a Concentrated Solar Power EOR project to use solar steam instead of burning gas to produce oil. Another solar project commenced lately in Dhofar in the Al Mazyonah rural

⁷⁵⁹ Interview with an official, Minister of oil and Gas.

⁷⁶⁰ Kazem, H.A., 2011. Renewable energy in Oman: Status and future prospects. *Renewable and Sustainable Energy Reviews*, 15(8), pp.3465-3469.

area using thin film photovoltaic modules and poly-crystalline technology, generating together 303 KW per year. In addition, a wind-based pilot project that will generate 500 KW of energy per year has been already approved by RAECO to be located in island of Masirah.⁷⁶¹

Previous studies highlight that several locations in Oman have high potential of harnessing renewable energies (Kazem, 2011;⁷⁶² Al-Badi A, 2012;⁷⁶³ Al- Yahyahi, 2010;⁷⁶⁴ AER, 2009;⁷⁶⁵ Al Ismaili, 1997⁷⁶⁶). According to the CEO of Masdar (a renewable energy company based in Abu Dhabi, which will lead the Masdar City project to create a city reliant only on renewable energies), Oman has a massive untapped potential for renewable energy, specifically in solar and wind power. He also notes that “The Dhofar wind power project will play an important role in supporting the diversification of Oman’s energy mix, while providing a reliable source of clean power to serve its growing population and economy” (Mohamed Al Ramahi, 2017).⁷⁶⁷

Several respondents pointed out some reasons for Oman to consider renewable energies in the national energy policy. They regarded the positive effects of renewables as a key reason that they should not be disregarded in a national energy policy. Three key positive points emerged for diversification by adopting renewable energies: changes in cost, good opportunities for diversification, and the potential of increased energy security.

⁷⁶¹ Al-Badi, A.H., Malik, A. and Gastli, A., 2009. Assessment of renewable energy resources potential in Oman and identification of barrier to their significant utilization. *Renewable and Sustainable Energy Reviews*, 13(9), pp.2734-2739.

⁷⁶² Kazem, H.A., 2011. Renewable energy in Oman: Status and future prospects. *Renewable and Sustainable Energy Reviews*, 15(8), pp.3465-3469.

⁷⁶³ Al-Yahyai, S., Charabi, Y., Gastli, A. and Al-Badi, A., 2012. Wind farm land suitability indexing using multi-criteria analysis. *Renewable Energy*, 44, pp.80-87.

⁷⁶⁴ Sultan, A.Y., Charabi, Y., Gastli, A. and Al-Alawi, S., 2010. Assessment of wind energy potential locations in Oman using data from existing weather stations. *Renewable and Sustainable Energy Reviews*, 14(5), pp.1428-1436.

⁷⁶⁵ AER (2009) Study on renewable energy resources. Muscat: Authority for Electricity Regulation Oman.

⁷⁶⁶ Al-Ismaily, H.A. and Probert, S.D., 1997. Energy overview for the sultanate of Oman. *Applied energy*, 57(4), pp.287-325.

⁷⁶⁷ Esi-africa.com. (2017). Oman: first large-scale wind farm to be developed in GCC. [online] Available at: <https://www.esi-africa.com/oman-first-large-scale-wind-farm-to-be-developed-in-gcc/> [Accessed 16 Sep. 2018].

7.4.1 Renewable energies are becoming more competitively priced

One of the participants (IO13, 2015)⁷⁶⁸ explained that the difference in price between renewables and conventional energies such as oil and gas is decreasing, making investment in renewable energies increasingly attractive. He also believes that the market itself will regulate the final energy mix—ie, an increase in renewable technologies in the domestic market will lead to the government creating regulations for this sector. A study by the Engineering College of Sultan Qaboos University showed that in the Marmul rural area, the cost of generating electricity from the solar plant was similar to that of diesel-based electricity generation, without considering the environmental benefits of an estimated reduction of 6,000 tons of greenhouse gas emissions that would have been produced by burning diesel.⁷⁶⁹ One study of a wind power project in the Duqum region showed that the cost of wind electricity was higher than that of the current gas-based electricity system. According to the study, the wind power was more costly because of the subsidised prices of local available natural gas. However, when the global market prices of natural gas are used for the comparison, the cost of gas-generated electricity is four times higher, and wind power becomes cheaper.⁷⁷⁰

7.4.2 Diversification opportunities

The majority of respondents thought that solar and wind resources were the most feasible technologies for Oman's environment, due to the availability of sun radiation throughout the year as well as a sufficient wind intensity. Overall, solar energy was considered most feasible of the two. One academic participant stated:

"I believe that Oman has the highest intensity of solar energy in the world, and there is a good potential to extract this energy because the sun shines at least 300 days per year, making it a promising energy source for Oman" (IA19, 2015).⁷⁷¹

⁷⁶⁸ Interview with an official, Secretary General of the Research Council

⁷⁶⁹ Al-Badi, A.H., Albadi, M.H., Al-Lawati, A.M. and Malik, A.S., 2011. Economic perspective of PV electricity in Oman. *Energy*, 36(1), pp.226-232.

⁷⁷⁰ Albadi, M.H., El-Saadany, E.F. and Albadi, H.A., 2009. Wind to power a new city in Oman. *Energy*, 34(10), pp.1579-1586.

⁷⁷¹ Interview with an academic, Caledonian College of Engineering, Research Professor and Head Caledonian Centre for Creativity and Innovation.

Another interviewee (IO17, 2015)⁷⁷² claimed that the entire energy requirements of Oman could be met by solar power, and that solar power is preferable to oil-based sources because it emits less CO₂. Many respondents agreed that wind was also a feasible candidate for Oman's energy diversification, although most thought it had less potential than solar power. An academic interviewed participant pointed out that the Authority of Electricity Regulation had done a study that found solar was more practicable than wind-generated energy, which was only feasible in specific locations (IA6, 2015).⁷⁷³

However, despite the common view that strong potential exists for renewables in Oman, a few interviewees also mentioned some associated challenges. First, high temperatures in Oman could adversely affect the generation of electricity from solar panels, because solar panels produce electricity less efficiently when they experience high temperatures. Second, dust is a common problem in Oman, and it can affect the functioning of solar panels. Third, solar power is intermittent, which means that output is dependent on the availability of sunlight. One respondent (IA18, 2015)⁷⁷⁴ said that because solar energy would not generate anything during the night, the energy system has to have a backup during these times to maintain the required level of electricity production.

7.4.3 Energy security

Energy security was brought up as another key advantage of a diversified national energy portfolio, because reliance on a wider range of energy sources increases stability and decreases the negative effects from any fluctuations of one resource. One respondent (IO13, 2015)⁷⁷⁵ stated that renewable energies can especially contribute to energy security in remote areas.⁷⁷⁶ A government official described similar situation by stating:

“Solar and wind energy can play an important role, especially when they are implemented off-grid to serve arid areas. People are spread across

⁷⁷² Interview with an official, Chairman of Peaceful Nuclear energy, Ministry of Foreign Affairs

⁷⁷³ Interview with Sultan Qaboos University (SQU), Associate Professor at SQU: Department of Electrical and Computer Engineering

⁷⁷⁴ Interview with an academic, Sultan Qaboos University, Professor at Department of Electrical and Computer Engineering

⁷⁷⁵ Interview with an official, Secretary General of the Research Council

⁷⁷⁶ Oman's terrain varies from desert, valley to mountains. Some of areas electricity grid cannot reach due to the difficult accessibility.

different areas of the country, making it difficult for the conventional electricity grid to reach these areas” (IO15, 2015).⁷⁷⁷

Several respondents (IO17, 2015;⁷⁷⁸ IA19, 2015;⁷⁷⁹ IO4, 2015⁷⁸⁰) agreed that energy security is a very important factor for achieving energy sustainability, especially when the literature proposed that the peak oil point of Omani oil production has been reached and now possibly in the decline trend⁷⁸¹. One academic participant stated the following view:

“In general, we can see that Oman has been progressing and developing over the last four decades, and this development is associated with growing domestic electricity demand, which mainly comes from burning natural gas for power generation. However, natural gas is becoming scarce and this hinders the progress in industrial expansion and other gas-powered applications. Now, replacing some of the hydrocarbon-based electricity with renewable energy resources could save Oman on local consumption and free up more natural gas to run its industry sector. Furthermore, using renewable energy technologies would improve not only Oman’s environment but also improve its energy security to achieve more sustainability” (IA18, 2015).⁷⁸²

Five main conclusions can be made in relation to the diversification of energy resources to achieve sustainable energy development in Oman. First, the reasons that renewable energy resources have not yet been introduced in the energy system are: that oil and natural gas are currently abundantly available for domestic use and export; subsidies for oil and gas create barriers against the uptake of renewable energy into the national energy portfolio; absence of legal framework and slow validation processes can cause delays in policy making; some practical challenges of the use of renewable technology in Oman exist, such as the effects of high temperatures and dust on solar panels; and high initial capital investment is required for renewable technology and infrastructure. Second, despite these barriers, renewable energy resources remain attractive for many reasons. For example, Oman gets some of the highest intensities of solar energy in the world and the total energy requirement in Oman could in

⁷⁷⁷ Interview with an official, Chairman of the Public Authority for electricity and Water

⁷⁷⁸ Interview with an official, Chairman of Peaceful Nuclear energy, Ministry of Foreign Affairs

⁷⁷⁹ Interview with an academic, Caledonian College of Engineering, Research Professor and Head Caledonian Centre for Creativity and Innovation

⁷⁸⁰ Interview with an official, Manager of Renewable Energy Research: The Research Council

⁷⁸¹ Group, B., 2009. BP Statistical Review of World Energy, June 2009. Nuclear Energy www.bp.com/statisticalreview. doi:bp.com/statisticalreview

⁷⁸² Interview with an academic, Sultan Qaboos University, Professor at Department of Electrical and Computer Engineering

theory be met by solar energy; the costs of renewable technologies are reducing and becoming more competitive with traditional resources; and Oman generally offers good opportunity for diversification. Third, energy diversification could be important in enhancing energy security through spreading reliance over a wider range of energy resources, thus increasing stability and decreasing the adverse effects from any fluctuations in cost or availability of any individual resource. Fourth, renewables could be crucial to implementing off-grid services for rural areas.

7.5 Environmental protection in Oman

This section provides an analysis of participants' views of the impact of energy consumption on the environment and whether incentive schemes promote the use of clean energy resources. As predicted by sustainable development theory (see chapter two for details), oil and natural gas have had an adverse effect on the environment, despite efforts of the Ministry of Environment and oil companies.⁷⁸³

The Omani government is aware of the importance of sustainability in environmental planning, and Oman has been implementing the 5-year development plans for Vision 2020, which aims to overcome the various developmental challenges in the country, including environmental aspects such as preserving non-renewable natural resources. The government has created various legislative initiatives to achieve their sustainable development goals and to ensure the availability of local natural resources for future generations. For example, the Marine Pollution Control Law, which is considered the main block of national environmental legislation, was established by a royal decree in 1974 to prevent dumping of waste into waters surrounding Oman and preserve the natural ecology of the area. In 1979, a royal decree established the Board of Environmental Protection and Pollution Control, which was considered the foundation of environmental institutions for the country.⁷⁸⁴

Oman joined the Kyoto Protocol in 2005, taking up commitments to reduce greenhouse gas emissions. Furthermore, the Ministry of Environment and Climate Affairs has worked to protect the environment and preserve the natural resources as well as to tackle all types and

⁷⁸³ Under the Corporate Environment Affairs, PDO operates in an environmentally responsible fashion to ensure all activities follow the standards of ISO 14001 and environmental plans.

⁷⁸⁴ MECA (2012) The National Report on Sustainable Development. Muscat: Ministry of Environment & Climate Affairs.

sources of pollution. For example, the Ministry has issued regulations for climate affairs management and for the establishment of the Clean Development Mechanism and the Designated National Authority. Some of the key development elements on environment protection in Oman are listed in the table 7-4 below.⁷⁸⁵

Table 7- 4: Key development elements on environment protection

Year	Key development elements
1974	Set up the Office of the Advisor of Environmental Protection
1979	Started the Board of Environmental Protection and Pollution Control
1985	Amended the Ministry of Environment to the Ministry of Environment and Water Resources
1985	Amended the Council of Environmental Protection and Pollution Control to the Council for the Protection of the Environment and Water Resources
1989	Developed the Ministry of Water Resources
1990	Amended organisational structure of the Ministry of Environment after the development of the Public Authority of Water Resources
2005	Became a member of Kyoto Protocol
2007	Established the Ministry of Environment and Climate Affairs by royal decree
2008	Amended the organisational structure of the Ministry of Environment and Climate Affairs and approved its terms of reference

Source: Compiled by the author, 2016

In addition, the National Strategy for Environmental Protection and Conservation was approved and implemented in 1995 by the Council of Ministers at that time. The key achievements of this strategy are as follows:

1. Renewable energy: developed an exploration programme for local renewable resource as a national priority
2. Sustainability: suggested policy frameworks for connecting environmental protection initiatives with development processes
3. Examination and evaluation: created a system to assess accomplishments in relation to environmental protection and conservation

⁷⁸⁵ MECA (2013) Initial national communication under the United Nations framework convention on climate change. Muscat: Ministry of Environment and Climate Affairs.

4. Integrated resource management: defined the significance of sectorial integration and collaborative methods in national resource management

However, the energy sector in Oman is operated under non-renewable energy resources, consisting of 97.5% natural gas and 2.5% oil.⁷⁸⁶ In this regard, all participants acknowledged the importance of clean energy resources on the positive effects of the environment and most participants agreed that incentives to introduce renewable energy resources can play big role on environmental savings. According to a respondent from an electricity company:

“The government should encourage renewable energy resources in the energy sector through well planned policies. I think incentives are good tools to support people to use these renewables and protect the environment, but again the government is the main player that can make this happen” (IEC3, 2015).⁷⁸⁷

Another participant from an oil company added that:

“I think incentives are more effective than penalties, they encourage more people to move in the direction of renewable energy applications, but these incentives need to be studied and examined against the entire energy system. Incentives are costly and might not be beneficial without assessing the energy system and examining where best to allocate the incentives to save the environment from emissions” (IOC1, 2015).⁷⁸⁸

However, according to Sharples and Taleb (2011), it is extremely uncommon in oil-exporting countries, such as those in the GCC, for governments to incentivise the use of renewable energy for the end-user.⁷⁸⁹ One participant from the academic sector underlined the importance of government intervention:

“Incentives for clean energy definitely have to be amended in energy policy. Particularly, it is important to encourage consumers to install solar panels on their houses since the prices of running and installing these technologies

⁷⁸⁶ NCSI (2016) Statistical yearbook. Muscat: National Centre for Statistics and Information.

⁷⁸⁷ Interview with Electricity Company, Chief Executive Officer, Rural Area Electricity Company (SAOC)

⁷⁸⁸ Interview with oil company, Retired Director from Petroleum Development Oman (PDO)

⁷⁸⁹ Taleb, H.M. and Sharples, S., 2011. Developing sustainable residential buildings in Saudi Arabia: A case study. *Applied Energy*, 88(1), pp.383-391.

are decreasing. But again, this incentive scheme is in the hands of the government to make it happen” (IA6,2015).⁷⁹⁰

Despite the broad support for an incentive scheme to introduce clean energy resources similar to schemes in Europe, a few respondents felt that incentives might not be the main solution for Oman. The reasons were that incentives introduced a distortion of the energy pricing mechanism (IO13, 2015)⁷⁹¹ and that Europe has different specific socioeconomic and meteorological features to Oman (IOC12, 2015).⁷⁹²

Notably, although several Omani publications, including the Authority for Electricity Regulation Reports, agreed on the need to incentives clean energies, the views of the participants recorded through interviews were heterogeneous.

7.5.1 Adverse effects of climate change

Since the 1970s, Oman’s economy and population have grown rapidly, leading to a substantial rise in greenhouse gas emissions. Specifically, the energy, transportation, and industrial sectors are the main contributors to air pollution. These sectors are interrelated, whereby economic development promotes industrialisation and demand for new products and services by strengthening consumers’ purchasing power, which results in flourishing transportation and logistics sectors. Also, economic growth increases the quality of life of the population as health care is improved, which in turn increases life expectancy of the Omani population, resulting in population growth.⁷⁹³

According to the United Nations Framework Convention on Climate Change (UNFCCC), participating countries should take responsibility for meeting their country’s specific requirements and the needs of member countries with lower socioeconomic statuses, which arise from the adverse effects of climate change or the impact of the implementation of the

⁷⁹⁰ Interview with Sultan Qaboos University (SQU), Professor at department of electrical and computer engineering

⁷⁹¹ Interview with an official, Secretary General of the Research Council.

⁷⁹² Interview with oil company, New venture director, CC Energy Limit.

⁷⁹³ Abdul-Wahab, S.A., Charabi, Y., Al-Maamari, R., Al-Rawas, G.A., Gastli, A. and Chan, K., 2015. CO2 greenhouse emissions in Oman over the last forty-two years. *Renewable and Sustainable Energy Reviews*, 52, pp.1702-1712.

climate change response measures. The following characteristics of Oman mean the country is strongly affected by climate change.⁷⁹⁴

1. Oman is considered to be highly vulnerable to natural disasters, which are worsened by climate change. For example, over the past 10 years, Oman has witnessed tropical cyclones of increasing severity (Gonu: 2007, Phet: 2010, and Mekunu: 2018), for which the damages were estimated to be US\$ 5.2 billion.
2. The average rainfall in Oman is estimated at less than 100 mm per annum, with more than 95% of land classified as either desert or undergoing desertification. In many areas of Oman, the land degradation is already severe, such as in Al Batinah South, AlBatinah North, Ash Sharqiyyah South, Ash Sharqiyyah North, and Dhofar, and these changes are probably effects of climate change.
3. Some areas of Oman, such as Al Jabal Al Akhdar are considered to have very fragile ecosystems. The arid mountain ecosystem of Al Jabal Al Akhdar in the northern part of Oman is a vital area of unique geology, climate, biodiversity, geography, and history, and is very susceptible to climate change.

Most participants acknowledged the negative impact of climate change on Oman's environment and indicated that achieving a sustainable environment requires effective policies, which is the responsibility of the Ministry of Environment. An interviewed academic explained how the government has acted to improve air quality:

*“The Omani government has acknowledged the adverse effects of climate change on people's health and the environment. Therefore, the Ministry of Environment and Climate Affairs disseminated the national standards of air quality for Oman in 2014, which include regulatory standards that companies must follow” (IA22, 2015).*⁷⁹⁵

Many studies and reports have identified problems in the environment in Oman. For example, the World Summit on Sustainable Development Report was presented by Sayyied Assaad Al Said in a statement to encourage the private sector in Oman to consider environment-friendly

⁷⁹⁴ MECA (2013) Initial national communication under the United Nations framework convention on climate change. Muscat: Ministry of Environment and Climate Affairs.

⁷⁹⁵ Interview with an academic, Sohar University, Director of Environmental Research Centre

measures.⁷⁹⁶ The report concluded that the private sector must give due consideration to environmental protection by adhering to regulations and laws to minimise pollution and other hazards that jeopardise the environment.

In response to the report, the Ministry of Environment and Climate Affairs developed three essential preventative measures against climate change for immediate action: (1) evaluate risks of and vulnerabilities to climate change in Oman, by improving and targeting research, assessing current policies and creating new ones, and ensuring the management of actions taken to achieve the outcomes; (2) involve the public by increasing knowledge and building international alliances; and (3) ensure smooth implementation by finding the best feasible solution that can be used by the public to help achieve sustainable development. In 2012, the Ministry of Environment and Climate Affairs established six air quality monitoring stations in the industrial city of Sohar to monitor pollution. Also, the Ministry of Education aims to incorporate materials and concepts on environmental sustainability into the educational curriculum to teach students about climate change and encourage positive environmental attitudes.⁷⁹⁷

However, although the Ministry of Environment and Climate Affairs took many actions to achieve environmental savings, no clear policies and strategies focusing on climate issues have emerged. According to one interviewed government official:

“The main challenge in the environment sector is that the government has not yet developed national climate legislation or put strategies in place”
(IO4, 2015).⁷⁹⁸

Dubash et al (2013),⁷⁹⁹ highlighted countries that do not have climate legislation and strategy or coordinating bodies. Figure 7-11 shows the different levels of legislation across the world.

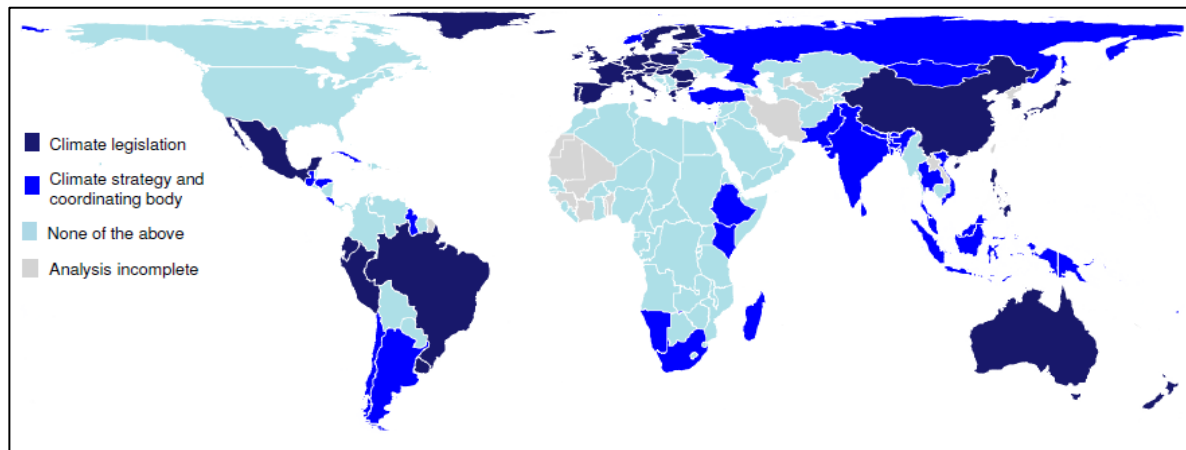
⁷⁹⁶ Summit, J., 2002. World summit on sustainable development. *Johannesburg, South Africa*. Oman Statement by his highness Sayyied Assaad Al-Said.

⁷⁹⁷ Abdul-Wahab, S.A., Charabi, Y., Al-Maamari, R., Al-Rawas, G.A., Gastli, A. and Chan, K., 2015. CO2 greenhouse emissions in Oman over the last forty-two years. *Renewable and Sustainable Energy Reviews*, 52, pp.1702-1712.

⁷⁹⁸ Interview with an official, Manager of Renewable Energy Research: The Research Council

⁷⁹⁹ Dubash, N.K., Hagemann, M., Höhne, N. and Upadhyaya, P., 2013. Developments in national climate change mitigation legislation and strategy. *Climate Policy*, 13(6), pp.649-664.

Figure 7- 11: Global map of climate legislation and strategies in 2012



Source: *Developments in National Climate Change Mitigation, Legislation and Strategy*, by Dubash et al., 2013.

From the figure it is clear that climate change issues are not central concerns of the policy-making groups in the GCC, possibly because implementing climate change measures would put constraints on the production of oil and natural gas, resulting in a reduction in revenues, which contribute substantially to the GCC budget.⁸⁰⁰

7.5.2 Greenhouse gas emission

Greenhouse gas emissions in Oman are mostly produced by energy extraction processes such as the combustion of fossil fuels for oil drilling activities, water desalination, transportation, and electricity production. This combustion of hydrocarbons is the main contributors to the generation of gases such as nitrous oxide (N₂O), carbon dioxide (CO₂), and methane (CH₄), which are recognised as waste products of energy.⁸⁰¹ According to an interviewed government official:

“If I may give an example in the oil sector, the process of extracting oil and natural gas from wells in Oman requires burning massive amount of gas to get steam, then reinjecting this steam into the wells. Those wells are very difficult to access because of the complex geological formation of the ground, which results in burning more gas to get access to the oil. Therefore, the process of extracting oil causes increasing emissions, and I think the

⁸⁰⁰ Hertog, S. and Luciani, G., 2009. Energy and sustainability policies in the GCC.

⁸⁰¹ Solanki, P.S., Mallela, V.S. and Zhou, C., 2013. Estimation and diminution of CO₂ emissions by clean development mechanism option at power sector in Oman. *International Journal of Energy and environment*, 4(4), pp.641-652.

government should give this issue priority in their environmental agenda”
(IO24, 2015).⁸⁰²

The coastal areas of Oman have high population densities and are the location of intense industrial activities such as steel and cement plants, oil refineries, and petrochemical plants. These factors are the most challenging areas in terms of air pollution in Oman.⁸⁰³ In addition, the extraction of the heavy and low-mobility oil in Oman requires more energy than conventional oil extraction, contributing further to CO₂ emissions.⁸⁰⁴

Imen Bachellerie anticipated that Oman’s total emissions will continue to increase at an average growth rate of 10% per annum over the next 40 years.⁸⁰⁵ According to an Arabia Supply Chain analysis report, electricity generation is the biggest contributor of CO₂, producing 39% of Oman’s total CO₂ emissions in 2014 (Figure 7-12). Because of the economic diversification plans towards industrialisation, industrial activities (especially the steel and cement industry) produce 37% of Oman’s total air pollution and transport produces 21%. The transport sector is expanding rapidly across the country, with an annual growth rate of 7% between 2015 and 2020.⁸⁰⁶

⁸⁰² Interview with an official, Director General of Planning and Projects Evaluation, Ministry of Oil and Gas

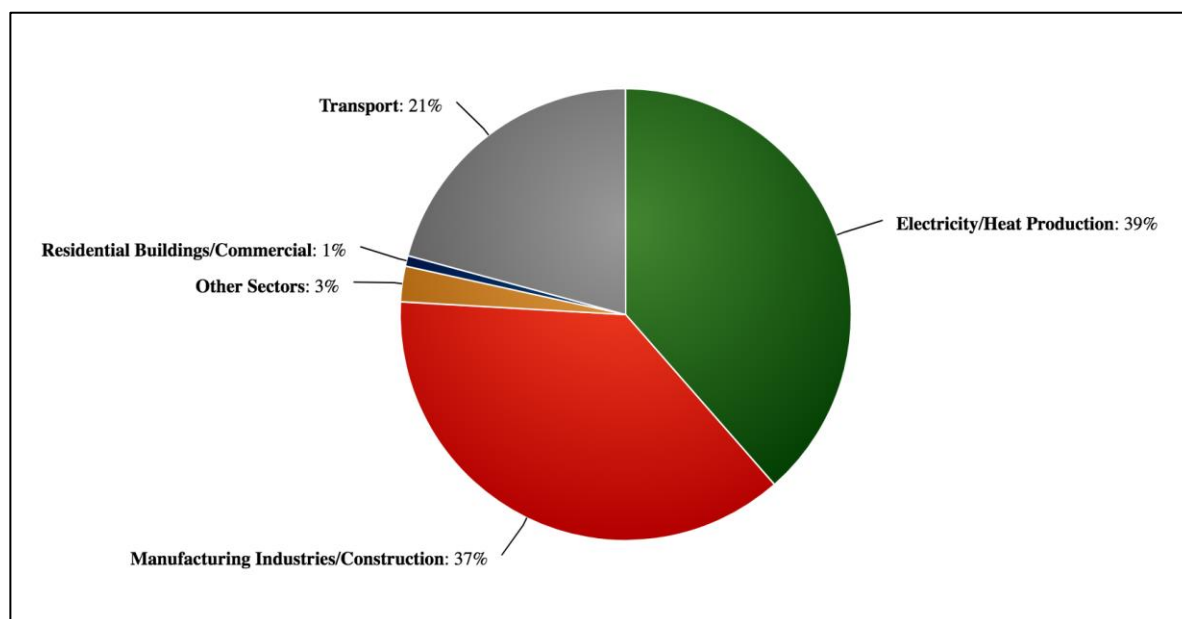
⁸⁰³ MECA (2013) Initial national communication under the United Nations framework convention on climate change. Muscat: Ministry of Environment and Climate Affairs.

⁸⁰⁴ Oil and natural gas fields use CO₂ injection in enhanced oil recovery techniques.

⁸⁰⁵ Bachellerie, I.J., 2012. Renewable energy in the GCC countries.

⁸⁰⁶ Logistics Middle East. (2016). ANALYSIS: Oman logistics industry's transformation. [online] Available at: <https://www.logisticsmiddleeast.com/article-12320-analysis-oman-logistics-industrys-transformation> [Accessed 16 Sep. 2018].

Figure 7- 12: Sectors' contributions to Oman's total CO₂ emissions in 2016



Source: compiled by the author from data obtained from World Development Indicators (WDI), 2016

In addition, one academic participant noted:

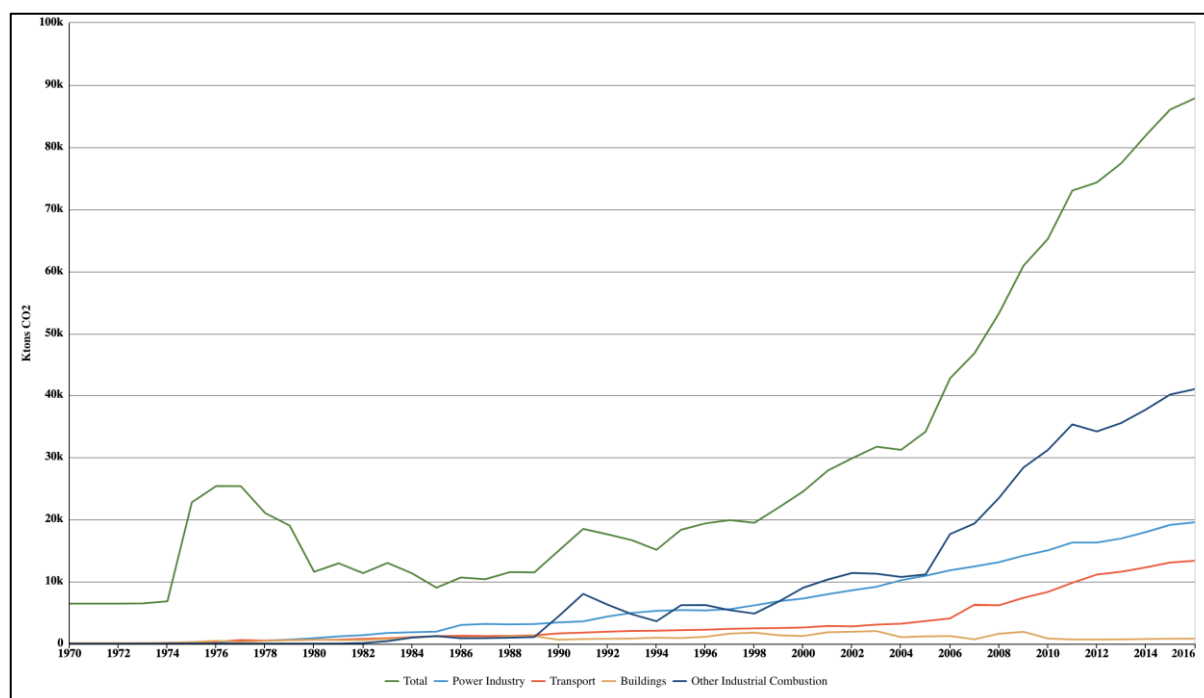
“The main fuels used for transportation are diesel and petrol, which contribute to the total CO₂ emissions alongside those from natural gas, which are even higher than those from oil because of the large quantity of gas used to power the industrial, residential, and energy sectors. Thus, it’s very difficult to maintain the Kyoto protocol” (IA7, 2015).⁸⁰⁷

In this regard, according to Parmal et al., 2013, CO₂ emissions from liquid fuel, gas fuel, and total fossil fuels increased by more than 140% between 2000 and 2009 (figure 7-13).⁸⁰⁸ This increase in CO₂ emissions is attributed to many factors, including 1) an expansion in manufacturing industries and the construction sector; 2) a rapid increase in the building of residential buildings; 3) a growing number of imported vehicles; 4) the expansion of the tourism sector; and 5) the construction of new power plants.

⁸⁰⁷ Interview with an academic, Sohar University. Director of Environment Research Centre

⁸⁰⁸ Solanki, P.S., Mallela, V.S. and Zhou, C., 2013. Estimation and diminution of CO₂ emissions by clean development mechanism option at power sector in Oman. *International Journal of Energy and environment*, 4(4), pp.641-652.

Figure 7- 13: CO₂ emissions by Total, Power Industry, Transport, Buildings, and other Industrial Combustion, 1970-2016



Source: Compiled by the author from data obtained from World Development Indicators (WDI), (2017)

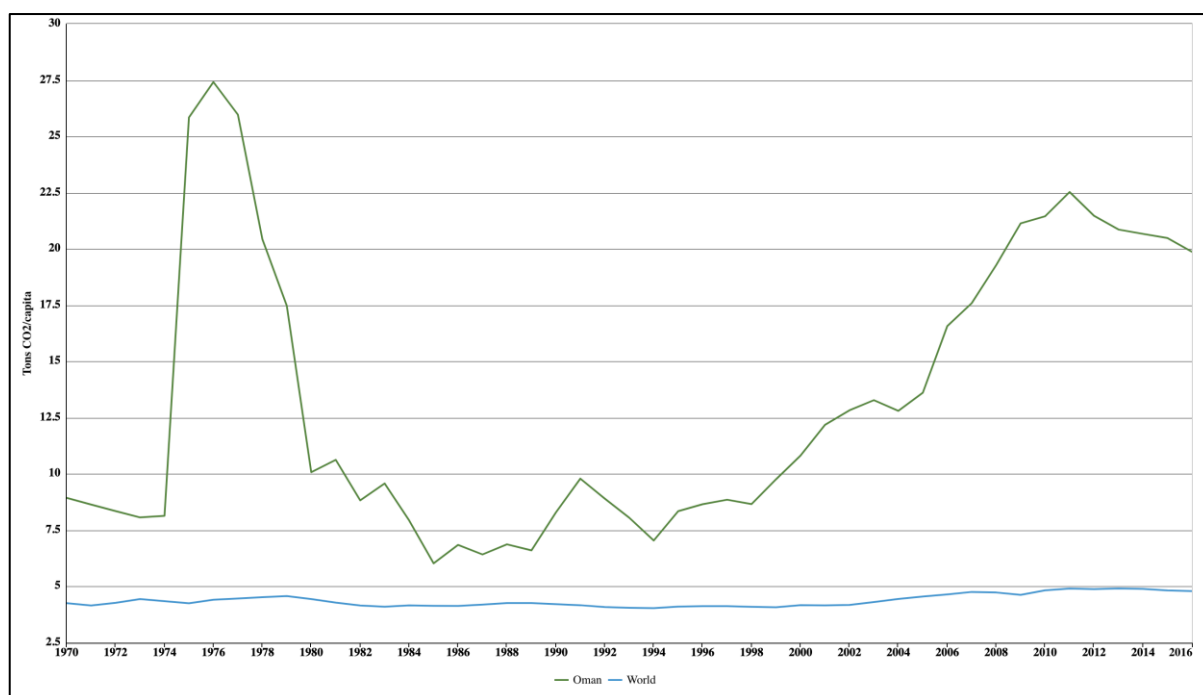
Furthermore, according to an oil company interviewee, oil's contribution to air pollution has also increased over the years, similar to natural gas. However, oil and other forms of energy will soon increase their contribution, because of upcoming new energy-intensive industrial projects and greater vehicle density on the roads (IOC1, 2015).⁸⁰⁹

Because of cheap tariffs in Oman, the average per capita carbon footprint has grown significantly since the 1990s. According to the United Nations Statistics Division, Omani per capita CO₂ emissions are five times greater than the world average, and dramatically higher than in other developing countries⁸¹⁰ (Figure 7-14).

⁸⁰⁹ Interview with oil company, Retired director form Petroleum Development Oman (PDO)

⁸¹⁰ Data.un.org. (2017). Oman greenhouse gas emissions. [online] Available at: <http://data.un.org/Search.aspx?q=Oman+carbon+> [Accessed 16 Sep. 2018].

Figure 7- 14: Per capita CO₂ emissions, 1970-2016



Source: Compiled by the author from data obtained from World Development Indicators (WDI), (2017)

The Ministry of Environment and Climate Affairs is aware of the issue of rapid increase in per capita CO₂ emissions, and established a pollution operations control centre to assess air quality and inspect the environment. However, no specific policy measures regulate per capita CO₂ emissions. According to an interviewed government official:

“I believe we should do something about each individual’s energy consumption. Individuals are consuming more energy than needed, because of the low prices of energy. I think we clearly require immediate policy measures that help to reduce CO₂ emissions and stop energy wastage, especially when considering that Oman is one of the less-industrialised countries of the world, but with a very high per capita carbon footprint” (IO24, 2015).⁸¹¹

Previous studies specify the importance of a clean energy resource to reduce the negative effects of fossil fuels on the environment (Hussein, 2011;⁸¹² A.H. Al-Badi et al., 2011;⁸¹³

⁸¹¹ Interview with an official, Director General of Planning and Projects Evaluation, Ministry of Oil and Gas

⁸¹² Kazem, H.A., 2011. Renewable energy in Oman: Status and future prospects. *Renewable and Sustainable Energy Reviews*, 15(8), pp.3465-3469.

⁸¹³ Al-Badi, A.H., Malik, A. and Gastli, A., 2011. Sustainable energy usage in Oman—Opportunities and barriers. *Renewable and Sustainable Energy Reviews*, 15(8), pp.3780-3788.

Steffen and Giacomo, 2009;⁸¹⁴ Ali et al., 2017⁸¹⁵). However, no environmental policy is in place to reduce the adverse effects of fossil fuels by implementing clean energies, such as renewable resources.

7.6 Conclusion

This chapter analyses the barriers that prevent the energy sector in Oman from achieving its energy sustainability goals. Through the analysis of the respondents' insights in the semi-structured interviews and the secondary data, growing concerns about the energy sustainability sector in Oman is evident. Despite the progress that the government has achieved over the past four decades in terms of development and expansion of the energy sector, the findings of this chapter indicate some remaining challenges that the energy system has to face. These challenges broadly include the need for energy sustainability policy, managing energy demands, and implementation of environmental protection measures. Creating coherent and comprehensive energy policies requires reliability, affordability, availability, and accessibility of modern energy services. Without these, the absence of national energy policy, which works in parallel with socioeconomic development strategy, will create a delay in achieving energy sustainability.

One of the main challenges that Oman will face if domestic energy demand continues to increase as rapidly as it does now is a scarcity of oil and natural gas supply. This will affect not only domestic use but also export, leading to lower export revenues. This chapter shows that the main causes of energy demand are attributed to six main factors: demographic changes and population growth, industrial expansion, the energy subsidies and their effects on energy consumption that result in wasteful attitudes and energy use behaviours, the poor implementation of energy conservation and demand-side management, and the absence of energy efficiency criteria for various sectors.

Other findings showed views on diversification of energy resources in the energy portfolio. Most respondents and various published studies confirmed that for the diversification of energy

⁸¹⁴ Hertog, S. and Luciani, G., 2009. Energy and sustainability policies in the GCC.

⁸¹⁵ Kazem, H.A., Al-Waeli, A.H., Chaichan, M.T., Al-Mamari, A.S. and Al-Kabi, A.H., 2017. Design, measurement and evaluation of photovoltaic pumping system for rural areas in Oman. *Environment, Development and Sustainability*, 19(3), pp.1041-1053.

resources, solar and wind were favoured for three main reasons: 1) these renewable energies are becoming cheaper and more competitive with non-renewable resources; 2) they enable diversification of the energy mix and are promising resources in Oman; and 3) they help increase energy security, in terms of supplying energy to difficult-access areas as well as the good sustainability of these resources.

Another key message of the findings of this study is the adverse effect of oil and natural gas and the contrasting contribution that clean energy resources could add to environmental savings. The Omani government is aware of the importance of sustainability in environmental planning. However, most participants confirmed the absence of national climate legislation and strategies that incentivise the replacement of some hydrocarbon-based electricity with renewable energy resources. It is important for the Omani government to react to Oman's energy situation, to protect against the problems that could be caused by depleting oil and gas reserves, and increasing pollution levels that threaten Oman's environment.

Chapter 8

Conclusion

8.1 Introduction

Energy diversification has played a pivotal role in enhancing the energy sector and is often helped improving energy sustainability.⁸¹⁶ Sustainable energy policies have influenced both social and economic development as well as being the driving force in achieving sustainable development.

This concluding chapter presents a summary of the research findings that have been drawn from the primary and secondary data in this study. The first section presents the research overview, key findings, and how the research questions were addressed. The second section describes the implications of the research findings for policymakers and its contribution to the existing theory and knowledge. The third section highlights the research limitations and the fourth section provides directions for future research.

This research study examined the role of energy diversification policy in achieving energy sustainability in oil-exporting countries, using Oman as a case study. It also analysed the fundamental importance of the existence of comprehensive and integrated national energy policy that can offer appropriate direction to the development of the entire energy sector as well as the potential to improve conservation and efficiency of energy usage. Sustainable energy policies would offer the opportunity to enhance Omani socioeconomic development while improving environmental protection.

8.2 Research overview and key findings

The aim of this study was to examine how energy diversification could enhance Oman's energy policy to achieve sustainable development. Four factors were identified through a review of the literature on sustainable development theory, and this research sought to identify how those factors might impact the energy sector and socioeconomic development. These factors can be classified into four broad categories: energy policy, domestic energy demand, diversification of energy resources, and environmental protection. Additionally, the study sought to identify

⁸¹⁶ Li, X., 2005. Diversification and localization of energy systems for sustainable development and energy security. *Energy policy*, 33(17), pp.2237-2243.

which of these factors were most influential in relation to energy sustainability policy and how the factors affect each other.

This study started with an introductory chapter that provided the research background, the main concepts, the gaps within the literature, the theoretical perspective of the research, and the significance and contribution of the research. The literature on energy diversification focuses mainly on oil-importing countries and topics such as energy security, diversification of energy supply, renewable energy, environmental protection, and efficiency and conservation.⁸¹⁷ Within the context of oil-exporting countries, the literature is more scarce and does not sufficiently explain how energy policy can be used in these countries to achieve energy sustainability. Many oil-exporting countries assume that because they have had an abundance of oil and natural gas energy resources for many years, they do not need to diversify their energy portfolios away from these depletable energy resources. This research aimed to fill these gaps in the literature to offer a better understanding of the performance of the energy sector for energy policymakers in oil-exporting countries. The introduction chapter also highlighted the justification for choice of Oman as a case study, gave a short overview of economy and labour force as well as the structure of this research.

Chapter two focused mainly on reviewing the literature on energy diversification and sustainability theory in the context of developed countries (where most research has been done thus far), with the aim of applying the findings to developing countries. The chapter developed the theoretical foundation for the study and identified the main gaps in the knowledge that require further scientific investigation. The analysis identified two key knowledge gaps that this research aims to contribute. First, in terms of sustainable development theory, previous research did not assess the four identified factors (energy policy, domestic energy demand, diversification of resources, and environmental protection) of energy diversification. These factors could help developing countries to achieve energy sustainability, but the existing theory did not adequately discuss how such factors could be implemented or understood in oil-exporting countries. Second, energy policy had not been analysed in any oil-exporting country. Sustainable development theory suggests that the heavy dependence on depletable energy resources in oil-exporting countries will encourage energy diversification to achieve

⁸¹⁷ Sustainabledevelopment.un.org. (2007). International Energy Agency (IEA):Sustainable Development Knowledge Platform. [online] Available at: <https://sustainabledevelopment.un.org/index.php?page=view&type=255&nr=1635&menu=35> [Accessed 16 Sep. 2018].

sustainability. However, the theory did not provide satisfactory solutions for implementation in these countries. The factors that influence the shift to more sustainable energy development remain poorly explained. Hence, this study offers a comprehensive analysis of energy sustainability factors in a single case study of Oman.

In addition, the literature on sustainable development does not propose planning policies to overcome issues related to sole dependency on depletable energy resources in the energy sector. Instead it offers a set of key elements for countries around the world to focus on when considering energy sustainability, such as adequate growth of energy supplies to meet people's needs, improving energy efficiency and conservation measures to minimise waste of primary resources, tackling safety and public health problems when they result from the use of energy resources, and protecting the environment by reducing pollution.

The broad review of the literature implies that most studies focusing on energy diversification concentrated mainly on oil-importing countries, and thus assess the diversification of energy resources, energy security of supply, and environmental impact of energy use (eg Omer, 2008;⁸¹⁸ Peter and Rebeka, 2007;⁸¹⁹ Gail, et al., 2011⁸²⁰)

Another group of studies (eg, Nathalie and Taylor, 2010;⁸²¹ Roger and George, 2018;⁸²² Pimentel et al., 2004⁸²³) focus on energy conservation and efficiency as the main element of sustainable energy development to lower energy consumption by avoiding future resource depletion. Other researchers (eg, Kreith and Goswami, 2017;⁸²⁴ Goran, 2008;⁸²⁵ Chamberlin

⁸¹⁸ Omer, A.M., 2008. Energy, environment and sustainable development. *Renewable and sustainable energy reviews*, 12(9), pp.2265-2300.

⁸¹⁹ Glavič, P. and Lukman, R., 2007. Review of sustainability terms and their definitions. *Journal of cleaner production*, 15(18), pp.1875-1885.

⁸²⁰ Cohen, G., Joutz, F. and Loungani, P., 2011. Measuring energy security: Trends in the diversification of oil and natural gas supplies. *Energy policy*, 39(9), pp.4860-4869.

⁸²¹ Trudeau, N. and Taylor, P.G., 2010. The energy efficiency dimension of energy security. *The Routledge handbook of energy security*. London: Routledge, pp.218-38.

⁸²² Kuhns, R.J. and Shaw, G.H., 2018. Conservation and Efficiency. In *Navigating the Energy Maze* (pp. 47-51). Springer, Cham.

⁸²³ Pimentel, D., Pleasant, A., Barron, J., Gaudioso, J., Pollock, N., Chae, E., Kim, Y., Lassiter, A., Schiavoni, C., Jackson, A. and Lee, M., 2004. US energy conservation and efficiency: Benefits and costs. *Environment, Development and Sustainability*, 6(3), pp.279-305.

⁸²⁴ Kreith, F. and Goswami, D.Y., 2007. *Handbook of energy efficiency and renewable energy*. Crc Press

⁸²⁵ Strbac, G., 2008. Demand side management: Benefits and challenges. *Energy policy*, 36(12), pp.4419-4426.

and Gellings, 1987;⁸²⁶ Gellings, 1985⁸²⁷) give attention to the demand-side management to enhance the energy system at the consumption side. Thus, most studies aiming to analyse energy diversification have tended to focus on security of energy supply; for example, Xianguo (2005),⁸²⁸ Dieter (2002),⁸²⁹ Bielecki (2002)⁸³⁰, and Asif and Muneer (2005)⁸³¹ study energy diversification using the energy security model to clarify the supply and demand of energy, whereas other researchers (eg, Hertog and Lucian, 2009;⁸³² Jebaraja and Iniyan, 2006⁸³³) use the energy sustainability model.

The second part of literature review in chapter two narrows the focus by reviewing the literature on the impact of energy performance on sustainability. Many scholars (Stirling, 1994;⁸³⁴ Skea, 2010;⁸³⁵ Sovacool, 2010⁸³⁶) argue that diversity of energy resources is crucially important for an energy system's long-term survival and is positively correlated to energy sustainability, minimising adverse effects of supply shocks and lock-in (getting stuck with one source of energy). However, other scholars (eg, Deffeyes, 2010;⁸³⁷ Shafiee and Topal, 2008;⁸³⁸ Tonn and Peretz, 2007;⁸³⁹ Birner and Martinot, 2002⁸⁴⁰) suggest that the adoption of energy efficiency

⁸²⁶ Gellings, C.W. and Chamberlin, J.H., 1987. Demand-side management: concepts and methods.

⁸²⁷ Gellings, C.W., 1985. The concept of demand-side management for electric utilities. *Proceedings of the IEEE*, 73(10), pp.1468-1470.

⁸²⁸ Li, X., 2005. Diversification and localization of energy systems for sustainable development and energy security. *Energy policy*, 33(17), pp.2237-2243.

⁸²⁹ Helm, D., 2002. Energy policy: security of supply, sustainability and competition. *Energy policy*, 30(3), pp.173-184.

⁸³⁰ Bielecki, J., 2002. Energy security: is the wolf at the door?. *The quarterly review of economics and finance*, 42(2), pp.235-250.

⁸³¹ Asif, M. and Muneer, T., 2007. Energy supply, its demand and security issues for developed and emerging economies. *Renewable and Sustainable Energy Reviews*, 11(7), pp.1388-1413.

⁸³² Hertog, S. and Luciani, G., 2009. Energy and sustainability policies in the GCC.

⁸³³ Jebaraj, S. and Iniyan, S., 2006. A review of energy models. *Renewable and Sustainable Energy Reviews*, 10(4), pp.281-311.

⁸³⁴ Stirling, A., 1994. Diversity and ignorance in electricity supply investment: addressing the solution rather than the problem. *Energy Policy*, 22(3), pp.195-216.

⁸³⁵ Skea, J., 2010. Valuing diversity in energy supply. *Energy Policy*, 38(7), pp.3608-3621.

⁸³⁶ Sovacool, B.K. ed., 2010. *The Routledge handbook of energy security*. Routledge.

⁸³⁷ Deffeyes, K.S., 2010. *When oil peaked*. Hill and Wang.

⁸³⁸ Shafiee, S. and Topal, E., 2009. When will fossil fuel reserves be diminished?. *Energy policy*, 37(1), pp.181-189.

⁸³⁹ Tonn, B. and Peretz, J.H., 2007. State-level benefits of energy efficiency. *Energy Policy*, 35(7), pp.3665-3674.

⁸⁴⁰ Birner, S. and Martinot, E., 2002. The GEF energy-efficient product portfolio: emerging experience and lessons. *Global Environment Facility Monitoring and Evaluation Working Paper*, 9.

and conservation measures reduces the consumption of oil and natural gas and reduces dependence on oil and natural gas, because fossil fuels are diminishing resources.

The chapter also reviews the literature on energy diversification theory in relation to renewable energy resources in the GCC countries and specifically in relation to Oman. Studies about Oman and the GCC are largely based on secondary data (official statistics) offered by governments, which might be biased toward making statistics look attractive for international investors.

In addition, previous studies using the energy sustainability model do not confront the problem of how the subsidies in all GCC countries, including Oman, have a large effect on the oil and natural gas sector. The chapter also identifies the potential for use of renewable energy resources with some specific technologies in oil-exporting countries. The last part of the chapter offers an overview on the literature concerning oil and natural gas policies in importing and exporting countries and how they compare with those in Oman. The review showed that oil-exporting countries face major obstacles to energy diversification that are less of a problem for oil-importing countries. To make use of renewable energy resources, not only must a country be able to make large investments in the infrastructure, it must also be able to source the equipment required. Furthermore, knowledge of how to use and maintain such technology is needed for it to work efficiently and effectively. These factors are not major concerns in many oil-importing countries because of their location and specialist education, but many oil-exporting countries do not have these facilities. Last, the literature on global energy diversification, and the political dimensions- of such policies are reviewed. Oil-exporting countries such as those in the GCC and the Middle East have generally shown less political will toward diversification of energy resources than other regions, including the USA and European Union. For example, GCC countries do not have any renewable energy in their energy system, whereas many oil-importing countries do.

Chapter three provides the conceptual and theoretical framework to guide the data collection and analysis process of this exploratory research. Instead of using a grounded theory, existing theories and studies were adopted to guide the study. Building on previous studies on sustainable development, the conceptual framework proposes four interconnected factors that influence the performance of energy sustainability. These factors are energy policies, domestic

energy demand, energy diversification, and environmental protection. This framework outlines the implementation process of the study and offers the researcher assumptions about the data collection and analysis process. For example, the Omani government has been using a series of 5-year socioeconomic development plans and Vision 2020 over the past 40 years, yet it has not successfully achieved its goals in relation to energy sustainability. The study shows that some of the issues associated with this policy planning are because of the fluctuations of international oil prices, whereas other problems have resulted from setting overly ambitious targets.

Chapter four presents a clear and comprehensive overview of the case study of Oman. It provides detailed information about the energy sector of Oman in terms of oil and natural gas resources and energy sustainability in this sector in terms of energy production and consumption, showing that oil extraction is not sustainable at the current rate of extraction with increasing energy demands. Furthermore, the chapter highlights the energy sector from the point of view of Vision 2020 and investments. It is apparent that Oman is unlikely to meet the targets of Vision 2020 to reduce dependence on oil's contribution to GDP from 42% in 2010 to 9% in 2020, mainly because there is no specific energy strategy for sustainability and diversification. The chapter discusses the structure of the electricity and water sector in terms of policies and regulations, including energy pricing, subsidies, and tariffs. Currently, the government subsidises about 45% of total production and distribution costs of electricity used locally. The challenges facing the electricity sector are discussed, including the tariff structure that should be developed to manage the excessive use of electricity, specifically for the domestic sector. However, the cost of electricity per unit is very low, and so the government offer subsidies to compensate distribution companies. Furthermore, cheap energy from oil and gas cause challenges to developing renewable energy resources, which require initial investment.

Chapter five justifies the selection of the qualitative case study as the most appropriate design for this study, as well as the research methods used for data collection and analysis. Furthermore, the chapter presents ethical considerations and concerns, such as dealing with topics that respondents might view as sensitive. For example, focusing on certain themes in the interviews could result in the respondents attempting to prevent answering politically sensitive questions. The chapter also discusses the research limitations.

Chapters six and seven analyse the primary and secondary data gathered in this study, including from interviews and publications. Chapter six analyses the factors related to planning policies that prevent the energy sector from achieving energy sustainability. It describes the strong relationship between energy performance (eg, natural gas extraction rates) and economic performance (eg, expansion of the industrial sector). The chapter also found that the 5-year development plans and Vision 2020 have been affected by global fluctuations of oil prices. However, it is clear that various challenges face Oman achieving its Vision 2020 targets, and aspects of the Omani energy sector still contradict the implementation of energy sustainability measures.

The chapter shows that the energy planning policies in Oman are insufficient to lead the country toward sustainability. The fluctuation of oil prices has negatively affected the implementation and processes of planning policies as use of fossil fuels had to be increased to maintain economic stability, so that many 5-year sustainability targets were not achieved. Another issue that needs to be solved is the failure to achieve a shift from an oil-based economy to a more sustainable economy by reducing dependence on hydrocarbons, as per the aims of Vision 2020.

Chapter seven analyses the empirical findings of this study in relation to the four categories of barriers that prevent the energy sector from achieving its energy sustainability: insufficient energy policies, high domestic energy demand, poor diversification of energy resources, and insufficient environmental protection measures. The chapter analyses Oman's energy policies, including the final 5-year development plan of Vision 2020 for 2016–20. The chapter explains the main causes of high energy demand in Oman, such as demographic changes and population growth, industrial expansion, energy subsidies, high energy use per capita, poor energy conservation and demand-side management, and poor energy efficiency. The chapter also assesses diversification of energy resources, including competitiveness and energy security, finding that the price difference between renewable and non-renewable energy types is shrinking, making investment in renewable energies increasingly attractive. The environmental concerns such as adverse effects of climate change and greenhouse gas emissions are analysed and the findings showed that although the Omani Ministry of Environment and Climate Affairs made many attempts to increase environmental protection, yet no clear policies and strategies focusing on climate issues have emerged.

One of the main conclusions of chapter seven is that a coherent and comprehensive energy policy is crucially required in the Omani energy sector to achieve reliability, affordability, availability, and accessibility of modern energy services, and thus, energy sustainability. The chapter shows that energy subsidies have a negative impact on energy consumption by encouraging wasteful energy use behaviours and that solar and wind energy resources are ideal candidates for the diversification of energy resources because of the natural climate and abundant available land space in the country.

Moreover, the analyses in chapter six and seven highlight how the Oman energy sector has suffered and continues to suffer from poor implementation of energy conservation and demand-side management measures that are outlined in the sustainable development plans of Vision 2020. These are essential factors for managing energy consumption as well as implementation of energy efficiency criteria for various sectors. Furthermore, the adverse effects of oil and natural gas and the contrasting benefits of clean energy resources are clearly vital to environmental protection.

8.3 Research original contribution to knowledge and implications

It is expected that any scientific research contributes to the development of existing knowledge. This study helps to fill a broad gap in the literature in the context of energy diversification in the case of Oman. This study presents novel findings with regards to theory and knowledge, as well as findings relevant to policymaking relating to government officials, oil companies, and academia.

8.3.1 Implications and contribution to theory and knowledge

The theoretical proposal that the existence of energy diversification in the energy sector has a positive influence on energy sustainability and has been supported by empirical evidence for oil-importing countries (eg, Sovacool and Mukherjee, 2011;⁸⁴¹ Vivoda, 2009⁸⁴²). However, views on the effect of energy diversification on the energy sector of oil-exporting countries

⁸⁴¹ Sovacool, B.K. and Mukherjee, I., 2011. Conceptualizing and measuring energy security: A synthesized approach. *Energy*, 36(8), pp.5343-5355.

⁸⁴² Vivoda, V., 2009. Diversification of oil import sources and energy security: A key strategy or an elusive objective?. *Energy Policy*, 37(11), pp.4615-4623.

through policies and strategies, technology choices, and laws and regulations, are mixed (Steffen and Giacomo, 2009⁸⁴³; Laura, 2011⁸⁴⁴), suggesting a need for further research.

The theoretical research about using energy diversification to improve the sustainability of energy sector has thus far focused on developed countries in various regions such as Europe, America, and Asia. However, scarce attention has been paid to oil-exporting countries. In addition, there is remarkably little empirical research on national energy planning policies with regard to sustainability measures for the economy in general or specifically in the energy sector in oil-exporting countries. This study aimed to fill a gap in the international literature by assessing energy diversification in a specific category of oil-exporting developing countries, which are described as being reliant on depletable conventional energy resources and having unstable economic structures. This research thus contributes to the theory by studying energy diversification and sustainability in Omani energy sector, and the findings might be generalisable to include countries with similar energy and economic structure, such as GCC countries and other oil-exporting countries.

In Oman, energy diversification policies have previously been studied in a context where the existing policies in the energy sector in Oman are fragmented across the separate subsectors, and the energy sector has no clearly defined national energy policy or action plans in place. Moreover, these fragmented policies do not enable the integration and cooperation between various government bodies, often resulting in duplication of efforts.

This study investigated the relationship between energy diversification and the Oman energy sector. This makes an important contribution to knowledge by enabling better understanding of how energy diversification can be applied as a tool for improving and supporting the energy sector in oil-exporting countries as well as helping decision makers and policy makers in forming more effective and sustainable energy diversification policies.

As domestic energy efficiency in oil-exporting countries declines while global energy efficiency rises, there is an essential need for change in the energy sector policy agenda in oil-

⁸⁴³ Hertog, S. and Luciani, G., 2009. Energy and sustainability policies in the GCC.

⁸⁴⁴ El-Katiri, L., 2011. Interlinking the Arab Gulf: Opportunities and Challenges of GCC Electricity Market Cooperation.

exporting countries. For appropriate policies to be created, a better understanding of the barriers is needed, as well as analysis of the ability of a shift from a solely depletable energy sector to a more sustainable energy sector. Thus, the very limited literature on how decision makers and energy performance, recognising the potential benefits of energy sustainability through well designed and implemented policy as well as diversification, and the main gap between present theory and practice, make this a significant area for research. This study contributes to this main issue by offering new insights into the oil-exporting countries (GCC countries and others of similar energy and economic structures) for realising sustainability from energy diversification angle.

This study expands existing study on energy diversification in several perspectives. For example, various existing studies have provided a partial explanation of energy diversification factors by analysing only one of the factors or barriers of energy diversification. Such studies have dealt with the energy diversification as an approach to the security of energy.⁸⁴⁵ By contrast, this study provides a more complete picture of energy diversification policy by identifying these sets of factors in relation to their barriers (development planning policies; 5-year development plans and Vision 2020), domestic energy demand (population, industrialisation, subsidies, and conservation and efficiency), diversification of resources (renewable energy technologies, opportunities, and energy security), and environmental protection (climate change and greenhouse emissions).

This study is unique in terms of investigating stakeholders' opinions on a potentially crucial element in energy sustainability, including demographic changes and population growth, expansion of industrial areas and energy-intensive industries, energy conservation and demand-side management, people's attitudes and energy use behaviour, and effects of subsidies on energy consumption. This study argues that energy diversification and sustainable development depend largely upon government planning policies and their implementations. In addition, the case of Oman shows that the abundance and heavy dependence on hydrocarbons places structural limitations upon the planning policy processes.

⁸⁴⁵ Hofman, K. and Li, X., 2009. Canada's energy perspectives and policies for sustainable development. *Applied Energy*, 86(4), pp.407-415.

The development planning policies of Oman have largely not been examined by scholars. Goran (2008),⁸⁴⁶ Pohekar and Ramachandan (2004),⁸⁴⁷ Afga and Carvalho (2000),⁸⁴⁸ and Gobaisi et al. (1998)⁸⁴⁹ do examine planning policies processes through their analyses of the energy structure; however, this study offers for the first time an analysis of the 5-year development plans from the beginning of the development planning policies (1976–1995) until the end of the Vision 2020 (1996–2020) planning policies and their implications for the energy sustainability process.

8.3.2 Implications and policy recommendations for policy making

It is crucially important to highlight that implementing energy diversification policy contributes significantly to energy sustainability. Policymakers should thus seek to develop a comprehensive, coherent, and integrated national energy policy to ensure accessibility, reliability, affordability, and availability of energy supply not only to guide energy development but also socioeconomic development.

The success of developing and implementing national energy policy relies on three main elements, besides social and political parameters⁸⁵⁰. First, the presence of an independent entity with full authority is essential to operate and manage all related energy activities, which acts as a focal entity specifically for coordinating activities of ministries and government bodies. Second, this independent authority should define and deploy the best energy mix for the energy sector with renewable technologies as well as have the power to establish the conservation and efficient use of different types of energy across all sectors of the economy. Third, the implementation phase is a crucially important focus.

⁸⁴⁶ Strbac, G., 2008. Demand side management: Benefits and challenges. *Energy policy*, 36(12), pp.4419-4426.

⁸⁴⁷ Pohekar, S.D. and Ramachandran, M., 2004. Application of multi-criteria decision making to sustainable energy planning—a review. *Renewable and sustainable energy reviews*, 8(4), pp.365-381.

⁸⁴⁸ Afgan, N. and da Graça Carvalho, M., 2000. *Sustainable Assessment Method for Energy Systems: indicators, criteria and decision making procedure*. Springer Science & Business Media.

⁸⁴⁹ Afgan, N.H., Al Gobaisi, D., Carvalho, M.G. and Cumo, M., 1998. Sustainable energy management. *Renewable and Sustainable Energy Review*, 2, pp.235-286.

⁸⁵⁰ Energy sustainability is not only dependent on economic dimension but also on political and social dimensions.

Policymakers should consider reforming and reallocating energy subsidies. Energy subsidies are the key barrier to energy conservation in Oman, because they introduce inefficiencies in the market and create careless behaviour and unsustainable energy consumption among domestic users. Domestic residential and industrial electricity prices in Oman are substantially lower than global market prices. Thus, subsidies encourage not only expansion of energy-intensive industries but also negatively affect the balance of trade, because as more energy is used for domestic purposes, less is exported. This imbalance, in turn, creates a burden on the Omani public budget. According to the Authority for Electricity Regulation, the Omani government subsidised its electricity sector by at least US\$1 billion in 2016.⁸⁵¹ Subsidies discourage many sectors from adopting renewables because they make renewable technologies seem unattractive compared to the subsidised oil and natural gas options. Therefore, an important action is for policymakers to gradually increase energy prices to mitigate these negative consequences.

Policymakers should also seek to make buildings more energy efficient. Buildings in Oman are poorly designed and constructed, many being designed on the assumption of the indefinite availability of cheap energy resources. Most buildings in Oman do not have reliable insulation, efficient windows, shading, or efficient appliances. Households are responsible for about 50% of energy consumption, mostly because of air conditioning. Therefore, policies are needed to improve efficiency in both residential and industrial sectors.

This study presented the argument that Oman has great potential for harnessing renewable energy resources in its energy portfolio, specifically solar and wind resources. By diversifying the resources in the energy sector, security will be increased and the adverse effects from any price fluctuations in one energy type will be decreased. Use of renewable resources would also free up more hydrocarbons either for domestic industrial applications and power generation or for export. However, there are some challenges that policymakers need to address in order to diversify energy resources. The perceived abundance and marked dependence on oil and natural gas for domestic use and export; subsidies for oil and gas generating barriers against the uptake of renewable energy into the national energy portfolio; poor legal framework and slow validation processes causing delays in policy making; technical barriers to the use of

⁸⁵¹ AER (2016) Annual report. Muscat: The Authority for Electricity Regulation.

renewable technologies, such as high temperatures requiring energy for cooling and high levels of dust on solar panels; and the high initial capital investment required for renewable technology and infrastructure.

In terms of environmental protection, policymakers should address issues relating to greenhouse gas emissions, which are generated from energy extraction processes, such as the combustion of hydrocarbons for oil drilling, electricity generation, water desalination, and transportation. Although the Omani Ministry of Environment and climate Affairs has taken action to achieve environmentally friendly processes, the government has not yet created national climate legislation or put strategies in place to incentivise the replacement of some hydrocarbon-based electricity with renewable energy resources. Therefore, it is important for policymakers to respond to Oman's energy situation, to protect against the issues that could be caused by oil and gas reserve depletion and increasing pollution levels that threaten Oman's environment.

8.4 Limitations of the research

Significant efforts have been made for this research with regard to research design, fieldwork, and data collection and analysis. However, during the research there were several limitations:

- It is important to have reliable sources as well as timely and accurate statistics for better analyses. For this study, some references were accessed through websites that only offer general information and statistics about the energy sector of the country. This challenge is not limited to Oman, but most developing countries. Similar challenges are also found on government websites. These websites were used for collection contextual information about the energy resources in Oman, the level of energy production and consumption, and the issues these resources face. However, more in-depth information is required for a better understanding of the energy sector's performance and trends, in addition to the relation of the energy sector to the other sectors of the economy.
- The literature from Oman's energy sector in terms of policies and strategies is limited, and unavailable in many cases. This scarcity is partly because there are no clear technical details on formulation and implementation of policies and plans in the energy sector, making it difficult for researchers to establish some historical policy aspects.

- Oman does not have a national energy policy in place. There are some fragmented plans created by various governmental entities, but those plans generally aim to fill the gap between energy consumption and production in the short term, which does not help researchers in obtaining a clear understanding of the path and trends of energy development, performance, and behaviours and attitudes towards sustainability.
- This study was done using Oman as a case study. It might not be possible to generalise the findings from this study to other countries, but this research should still serve as a foundation for further investigation of energy sustainability in other oil-exporting countries, specifically GCC countries, where similar energy structures exist.
- The interviews done in Oman were designed for high-profile officials and policymakers, but these individuals do not have much spare time, especially when the interview took place in the holy month of Ramadhan. The processes of communication with these interviewees were very slow and took far more time than anticipated. This caused a conflict of appointments on several occasions, often when the interviewer received an approval to meet a high-profile official on a day that another meeting was already scheduled, so the interviewer has to delay one meeting, causing an extended wait of 4 weeks for another meeting. No planning framework existed from which to consider all alternative options and outcomes when meeting with high-profile officials.

8.5 Suggestions for future research

Clearly, Oman's energy sector would benefit from further research on various features of energy sustainability. Specifically, future research should be done in view of the following suggestions:

- Oman shares similar economic, social, and political structure with other GCC countries, thus the same framework can be applied for further research to study the energy sustainability attempts in the other GCC countries. In addition, the framework can also be used to study the four factors of energy sustainability theory (planning policies, domestic energy demand, diversification, and environmental protection) in the other GCC countries. Moreover, the framework of this research could also serve in global comparative studies; for example, the impact of the four sustainable energy factors on the oil-importing countries in comparison to oil-exporting countries.

- Research needs to be done to analyse the influence of planning policies on the reduction of energy demand on industrial and residential buildings.
- The attitudes of energy end users towards subsidies and the links to environmental protection could be investigated.
- The impact and influence of the fluctuation of oil prices on renewable technologies needs to be analysed, taking into consideration the distinction between oil importers and oil exporters
- The impacts of appliance efficiency standards in the Omani building sector to improve energy conservation and efficiency measures should be investigated.
- More research is needed to compare the performance of the Omani energy sector with that in other countries, specifically those that have similar energy resources to Oman.
- An investigation could be done to assess the attitude of local oil companies towards renewable technologies.

In summary, this research provides crucial insight into the way in which the energy sector has operated and performed in Oman, and the way that Omani energy policies have been put into practice. However, it must be noted that the development of the energy sector in Oman, and indeed development of the country as a whole, begun only a few decades ago, in 1970. A remarkable success has been achieved by the government in terms of reaching a general level of development, making use of natural resources in the energy sector to fuel the economy. However, the progress of socioeconomic plans and policies has been slow, which was unavoidable due to many factors such as inflexible policies, absence of proper implementation, and oil price fluctuations. The importance, not only in terms of energy, but also social, economic, and political aspects, for government planning policies is clear; to maintain what has been achieved so far and also to expand development across all sectors of the country.

Interviews with energy decision makers as part of this research indicated that the government is planning to set a new vision for the year 2040, to further modernise the country, and energy sustainability policies will be an essential factor if its long-term development plans and targets are to be achieved.

The implications for policy making for government officials, as well as for oil companies and other parts of the private sector, are clear. Decision makers and relevant parties can benefit

from the results of this study, which were analysed with a scientific approach, and use them to enhance the performance of the energy system and improve energy policies, in Oman and perhaps also other oil-importing countries. This chapter also highlights the limitations of this study, and the opportunities to improve future energy sustainability research.

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Appendices

Appendix (1): Supporting letter form The Research Council (TRC)

<p>Reference number:</p> <p>Date:</p> <p>Dear:</p> <p>After Compliments:</p> <p>We would like to invite you to participate in this interview "Energy Diversification in Oman's energy Policy", by Mr. Bader Ali Al Hinai, a staff at The Research Council, currently studying for a PhD at King's College, London, UK.</p> <p>The research objectives are to understand the effect of energy diversification in enhancing Oman's national energy policy by focusing on evaluating the impact of renewable energy resources on energy sector; to examine the rules and regulations that are needed to enhance the efficiency and conservation of the current energy usage; and to evaluate the effectiveness of national energy policy and the performance of the energy sector in achieving the objectives mentioned above.</p> <p>By completing this interview you are assisting in strengthening the information used for efficient energy diversification policy.</p> <p>For further information, please contact the Researcher Mr. Bader Al Hinai at 95555116 or Email: Bader.alhinai@gmail.com</p> <p>Hoping for your cooperation in the best of public interest</p> <p>Hilal Ali Zahir Alhinai</p> <p>Secretary General, The Research Council</p>	<p>رقم المرجع:</p> <p>التاريخ:</p> <p>الفاضل:</p> <p>تحية طيبة وبعد:</p> <p>نود دعوتكم للمشاركة في المقابلة الخاصة بـ " تنوع الطاقة في سياسة طاقة سلطنة عمان ". والذي يقوم به الفاضل/ بدر بن علي الهنائي، من مجلس البحث العلمي، وذلك في إطار دراسته لنيل درجة الدكتوراه من كنجز كوليدج، جامعة لندن (المملكة المتحدة).</p> <p>يهدف هذا البحث الى دراسة تأثير تنوع مصادر الطاقة في تعزيز سياسات الطاقة الوطنية في السلطنة من خلال تقييم أثر موارد الطاقة المتجددة في قطاع الطاقة ودراسة الأنظمة والقواعد اللازمة لتعزيز كفاءة الطاقة والحفاظ عليها. ويهدف البحث أيضا الى تقييم فعالية سياسات الطاقة الوطنية وأداء قطاع الطاقة في تحقيق الاهداف المذكورة اعلاه.</p> <p>لا شك ان تعاونكم في هذه المقابلة سوف يكون له أثر كبير في إضفاء المزيد من المعلومات المستخدمة لتعزيز سياسات تنوع مصادر الطاقة.</p> <p>لمزيد من المعلومات يرجى الاتصال بالباحث الفاضل/ بدر بن علي الهنائي على الهاتف رقم (95555116) أو البريد الإلكتروني bader.alhinai@gmail.com</p> <p>أملين منكم التعاون لما فيه الصالح العام.</p> <p>هلال بن علي بن زاهر الهنائي</p> <p>أمين عام مجلس البحث العلمي</p>
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Appendix (2): List of interviewees**List of Interviewers**

Code	Designation	Category
IOC1	Retired Director Petroleum Development Oman (PDO)	Oil Company
IEC2	Chief Executive Officer Oman Power and Water Procurement Co (SAOC)	Electricity Company
IEC3	Chief Executive Officer Rural Area Electricity Company S.A.O.C.	Electricity Company
IO4	Renewable Energy Research Manager The Research Council	Official
IO5	Chairman's assistant for International Relations Public Authority for electricity and Water	Official
IA6	Associate Professor, Chairman Sultan Qaboos University, department of Electrical and Computer Engineering	Academic
IA7	Associate Professor Sohar University	Academic
IA8	Assistant Professor Sultan Qaboos University, Department of Electrical and Computer Engineering	Academic
IO9	Assistant Professor Sultan Qaboos University, College of Engineering	Academic
IO10	Assistant Secretary General for Programs and Research The Research Council	Official
IOC11	Energy & Industry Director The Research Council	Official
IO12	New Venture Director CC Energy Limited	Oil Company
IO13	Secretary General of the Research Council	Official

	The Research Council	
IO14	Minister the Supreme Council for Planning	Official
IO15	Chairman the Public Authority for Electricity and Water	Official
IO16	Minister Ministry of Oil and Gas	Official
IA17	Chairman of Peaceful Nuclear Energy Ministry of Foreign Affairs	Official
IA18	Professor Sultan Qaboos University, department of electrical and computer engineering	Academic
IA19	Research Professor and Head Caledonian Centre for Creativity and Innovation Caledonian college of engineering	Academic
IA20	Professor Caledonian college of engineering	Academic
IA21	Assistant Professor Sohar University	Academic
IEC22	Director of Environmental Research Centre Sohar University	Academic
IO23	Executive Director Authority for electricity Regulation	Electricity Company
IO24	Director General of Planning & Projects Evaluation Ministry of Oil and Gas	Official
IA25	First Director of Renewable Energy Public Authority for electricity and Water	Official

I= Interview
 O= Official
 EC= Electricity Company
 OC= Oil Company
 A= Academic

Appendix (3): The interview questions



University Of London

PhD Interview Questions

Social Science and Public Policy

"The role of energy diversification policy in enhancing the sustainability of Omani energy sector"

INFORMATION SHEET FOR PARTICIPANTS

REC Reference Number: 14/15-101 - Diversification in Oman's Energy Policy

YOU WILL BE GIVEN A COPY OF THIS INFORMATION SHEET



Title of study: *The role of energy diversification policy in enhancing the sustainability of Omani energy sector.*

I am Badar Ali Alhinai, working at the Research Council, Oman. At present, I am a Ph.D. student in the energy policy field at King's College, London, undertaking a research entitled: ***“The role of energy diversification policy in enhancing the sustainability of Omani energy sector”***. I would like to invite you to participate in this research project which forms part of my PhD research. You should only participate if you want to; choosing not to take part will not disadvantage you in anyway. Before you decide whether you want to take part, it is important for you to understand why the research is being done and what your participation will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask me if there is anything that is not clear or if you would like more information.

The aim of the study is to contribute to the national energy policy and to understand the potential benefits of renewable energy resources in enhancing the diversification of the Oman's energy sector through policies and strategies, technology choices, and laws and regulations. The research objectives are:

- To understand the effect of diversification in enhancing Oman's national energy policy by focusing on evaluating the impact of renewable energy resources on energy sector.
- To evaluate the effectiveness of national energy policy and the performance of the energy sector in achieving the objectives mentioned above.
- To examine the rules and regulations that are needed to enhance the efficiency and conservation of the current energy usage.

To date, there has been no investigation in the case of Oman in terms of the above aims. Furthermore, a developing country like Oman is an exciting case because

renewable energy resources have great potential to diversify and sustain the energy resources, particularly in the oil and gas sector, and subsequently achieve more sustainability. This will involve an interview-based with you.

The interview will take approximately one hour and be based on the interview topic guide, but it is designed to be flexible so as to meet your needs. The interview will be recorded, subject to your permission. Recordings of interviews will be deleted after transcription. Even if you have decided to take part, you are still free to cease your participation at any time and to have research data/information relating to you withdrawn without giving any reason before 31 June 2016.

The UK Data Protection Act 1998 will apply to all information gathered within the interviews and held on password-locked computer files and locked cabinets within King's College London. No data will be accessed by anyone other than me; and anonymity of the material will be protected by using false names. No data will be able to be linked back to any individual taking part in the interview. You may withdraw your data from the project before 31 June 2016. All recordings of data on audio-equipment will be deleted after transcription. If you ask me to withdraw your data at any time before 31 June 2016 I will remove all traces of it from the records.

The Research Council of Oman is funding this research. For further information, visit: www.trc.gov.om . The study has been approved by the King's College London Research Ethics Committee

I will produce a final report summarizing the main findings, which will be sent to you upon your request. I also plan to disseminate the research findings through publication and conferences in both English and Arabic.

If you have any questions or require more information about this study, please contact me using the following contact details:

Badar Ali Alhinai
King's College London
Virginia Woolf Building
22 Kingsway
London
WC2B6NR
Badar.alhinai@kcl.ac.uk

If this study has harmed you in any way or if you wish to make a complaint about the conduct of the study you can contact King's College London using the details below for further advice and information:

Dr Ashraf Mishrif, Senior Lecturer in Political Economy
King's College London
Virginia Woolf Building
22 Kingsway
London
WC2B6NR
Tel: +44 (0) 20 78481798
ashraf.mishrif@kcl.ac.uk

Thank you for reading this information sheet and for considering taking part in this research.

Interview Questions:

Energy Policy:

1. As per your knowledge, is there a national energy policy?
2. Energy conservation plays a very important role within any energy policy. Do you think Oman should introduce such conservation measures such as the insulation of buildings to be in line with international standard through rules and regulations?
3. There were previous attempts by the government to introduce such regulations but at that time it was considered that measure would be against the interest of low income families because it adds to the cost of construction. Do you think this still applies? And would you support that the government subsidizes the uses of insulation for low income families?
4. What about renewables, do you think they have not yet been introduced properly in Oman's energy policy?
5. Do you believe solar and wind energy should have significant role to play in Oman's energy sector?

Energy Pricing:

6. Energy prices in Oman are currently subsidized, do you believe such subsidies should be removed or at least targeted to low income families through appropriate means?
7. Do you believe these subsidies can potentially hamper a transition towards a more sustainability energy supply demand?

Energy Demand:

8. The energy consumption in buildings is significantly impacted by the orientation of buildings in relation to the movement of the sun in the sky. Should the ministry of housing make this as important criteria in the design of housing plots?
9. Oman Power and Water Procurement (OPWP) currently uses the 7 year statement to ensure that the production capacity meets the expected demand. In your opinion, should this organization focus also on curbing the demand through improving energy efficiency in distribution and end-use?
10. As priority, what are the three top important measures to focus on?

Energy-Mix:

11. In your opinion, what are the feasible energy sources in Oman, including oil, gas, coal, renewable energy, and nuclear?

12. What percentage each could play in the energy-mix?

Environmental Concerns:

13. Should the government introduce incentive schemes as per international practices for the introduction of clean energy sources?